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Where Will You Be When You Get Where You're Going?*

By George Black

President, The George Black Company, Jacksonville, Florida

Ever since I can remember I've heard variations on the story of the inebriated gentleman searching vainly on the corner of Forty-Second Street and Broadway for a dollar bill lost in an alley almost a block away. When asked his reason, he replied without hestiation, "Couldn't see a blasted thing in that alley. Here at least a man has some light." It often makes me wonder how many of us are looking where the light is brightest for something we've lost elsewhere. How many of us are too busy going someplace to stop a while and find out where we will be when we get there?

Industrial Engineers have a lot in common with management consultants. In fact, I think it's safe to say that the majority of management consultants came through Industrial Engineering training or practice. My knowledge of manufacturing and system shortcuts doesn't come from books or actual work experience, but primarily through first-hand observation of literally thousands of plants. As a technical writer and editor and as an industrial advertising man who believes that the best industrial ad copy is written only through a thorough knowledge of a product and its use, I spent a good part of my life finding out how people do things, and then communicating these thoughts to others. But even with this experience I don't ever offer my services as an Industrial Engineer. Perhaps a better title for the type of work I do might be marketing engineer. You tell them how to make the product most economically. I tell them how to sell it. We both have this in common, however: Our jobs are based on our ability to make money for other people. You do it by cutting their operating costs; I do it by building their sales. If I seem to be laboring this identification between your job as an Industrial Engineer and my job as a marketing engineer, I am doing it with a definite purpose. I want you to feel that in the things we are trying to do and the places we are trying to go we have a lot in common, and therefore my experience and my thoughts are not those of an outsider or a stranger, but rather of a co-worker and a friend.

* Based on a presentation to the Jacksonville Chapter, AIIE, February 14, 1957.

Basic Problem of Industrial Engineering

Let us recognize the basic problem, not only in Industrial Engineering circles, market engineering circles, but in the entire universe. This problem is one of communications, of making people understand what you are trying to accomplish and what you are trying to say. Communication is accomplished through the use of the senses and is augmented or hindered through the use of the intellect. In the industrial field we communicate through the spoken and the written word, through the use of photographs, drawings, models, or through actual demonstration and witnessing. In most cases we combine a variety of these approaches. When talking to one of the men in the shop, for example, you not only use words, but you will use diagrams, and, if possible, the actual installation. When selling an idea to the boss, while seated in his office, words accompanied by sketches and photographs are your best means. The man who succeeds is the man who can get his story across clearly and concisely and who can go a step further and influence people to act on the basis of his findings. And so we see that the basic problem is one of communications.

Meeting the Challenge

But now, let us go back to the problem of—where are we going and where will we be when we get there? To start with, you are in a good profession. In a number of surveys conducted by the American Institute of Public Opinion, the engineering group has been listed among the two best professions for a young man to take up. Medicine is the other one. We are seeing more and more engineers moving up into management positions. And yet in spite of this, the public relations value of the engineer is taking a turn downward. I would just like to summarize briefly some of the reasons for this downward trend. One is the fact that there is no unified engineering body to speak for all engineers, in the way that the American Medical Association speaks for all doctors. Secondly, there is a strong drive toward specialization in engineering fields which is perhaps one of the reasons why we have no strong unified professional body. Thirdly, the greatest percentage of engineers are employees rather than individual practitioners of a

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profession. This employee complex with its identification with labor, rather than with management, hurts the public relations picture, and results to some extent in the fourth major reason—a poor professional attitude. It is not my intention to talk on the lofty plane of professional attitudes, but rather I would like to get down to brass tacks and say to you, "Mr. Industrial Engineer, what do you want out of life?" "Where do you want to go?" And I will try to point out some of the major things you can do to put more meaning in your job and make you more valuable to your company and your family.

Let us start with the assumption that you have attained your present position as an Industrial Engineer through competence. You may be college trained specifically in Industrial Engineering. You may have your college training in other fields, but your experience in Industrial Engineering. Or, you may have come up the hard way, through the ranks, and because of a talent and aptitude moved your way into Industrial Engineering circles. It really makes little difference how you got where you are today, provided you are competent. The first question to ask yourself is, "are you doing the type of work you enjoy?" If the answer is in the negative, you must go on yourself to ask why you don't enjoy it and make your own plans to get into something you really want to do. If your answer is in the affirmative, and I'm sure that with most of you it is, you must also ask yourself, "why?" Does it come from the fact that the paycheck is relatively high? Does it come from putting the needle in lazy workers? Does it come from clerical type listing and record keeping? Or does it come from meeting a challenge and licking it? You're my kind of man only if the answer is a resounding "yes" to the last question; that is, if the major pleasure of your job comes in the meeting of challenges and successfully licking them.

Acquiring Recognition

Now I'm going to stick my neck a long, long way out and say that I have never met a man who got his enjoyment from meeting challenges who didn't have a big ego to go along with it and that to satisfy this ego licking the problem is not enough. He wants to tell people about it, and he wants recognition for it. On the plant level you tell people verbally and through reports; and you get your recognition in a paycheck. This is fine, but it is not enough. It will never satisfy the ego completely. You want to receive recognition from people who fully realize the nature of the work you are doing, and with very few exceptions, the only people who can realize this are other Industrial Engineers. The only way you can get your story across to them and get their reaction in return is through group meeting, such as this, and through the preparation of articles in the trade press. And the wonderful thing about this ego which forces you to tell the things you are doing and to seek acclaim from those for whom you work and from those with similar interests is the fact that in satisfying your ego, you are helping others as well as yourself.

In order to make this meeting as personal as possible I'd like to take a few pages out of my own book and show you how this drive to communicate has played such a vital part in my own life.

Sixteen years ago I was an inspector in the detail manufacturing division of a large aircraft company. The day I reported for work I was given the choice of two jobs: (A) a machine shop precision parts bench inspector, or (B) an inspector in the finishing department. The former job demanded greater skill and paid more money, but I chose the job as finishing inspector, in spite of the fact that the pay was lower, and I needed every dollar. My reason was very simply this: I was told that the job of the finishing inspector required an understanding of all previous detail manufacturing operations, because in determining the finish for a part it was important that the part not be sent through finishing operations until previous machining work had been completed. I was also told that the finishing inspector had to know materials, because the type of material determined the type of inorganic type of finish it was to receive. I was also told that the finishing inspector had to know the final assembly and installation of the components because this very often determined the areas which had to be protected from the finishes, as well as the final color identification of the part. I was a green kid in a department completely staffed with the old guard who believed that "the less I teach this man, the less danger he will be to me." And for the most part my superiors were not concerned with what or how I learned, but the ego was so strong that I soon began to write what might be called "self-training manuals" which were in essence summaries of things that I felt were valuable for a man with my responsibilities. As the department grew my "manuals" began to be used by others, and in no time at all I began to rewrite these self-training manuals and articles in form suitable for the various trade journals. Perhaps the biggest factor in my leaving the position of inspection foreman, which I had attained after five years of work, was the fact that a company policy closed the doors on communication.

When I joined The International Nickel Company, my major job was the preparation of technical stories on successful applications of nickel bearing materials. For two years this took me all over the country and into the greatest possible diversity of plants.

During the next five years, as Public Relations Director for Cooper Alloy Corporation, I branched out using all the means of industrial communication including advertising, direct mail, catalogs, etc. By the time I opened my own business; which has as its basis the problem of building sales by closing the communications gap, I had lived more than a dozen years in pursuit of the same aim; namely, licking problems and telling people about it, or just finding problems which other people had licked and helping them to tell other people about them. One of my biggest current assignments is the problem of building sales by improving communications for an industrial distributor.

Communications

I have gone to great lengths to show you how my own personal life and work have been tied up with this idea of meeting problems on the industrial level and translating them or communicating them to other people, because I sincerely believe that this is the primary interest of most Industrial Engineers. Your Institute is one of the best methods you can find to help you exchange ideas with people whose interests are similar to yours, with people whose problems are akin to those you face. Where else will you find an audience who will listen to you, learn from you, and perhaps teach you in return? Don't sell this group short! Perhaps the attendance has been small and the membership not up to its potential because you haven't sufficiently clarified the goals of AIIE and your own individual goals. There is hardly a company in this area which would not support and encourage membership in your organization if the top men were approached and explained in no uncertain terms that your prime purpose was to exchange ideas and know-how, with the end result of cutting operating and production costs.

Summary

To build your Institute and make it even more worthwhile, you need to provide an opportunity to release the ego and get recognition. Just about every meeting should result in a publishable paper—in a presentation you'll find valuable and worthy of reporting to higher ups. As Industrial Engineers your value is determined by your ability to cut operating costs, speed production, or improve the product. This gives you plenty to talk and write about. This is a creative phase of engineering; therefore, if you are cut out for this job, you are a creative person. If you are a creative person, you've got a big ego, and that ego will only be satisfied through recognition of the work you are doing or have done. Recognition from your employer in the form of higher salary is always welcome, but it is not enough. Recognition from your fellow Industrial Engineer who understands thoroughly the nature of your work will give you the biggest possible emotional lift. This recognition from your fellow Industrial Engineer comes basically in two ways; in writing for the technical and trade journals and in close association through groups such as the AIIE. Your company, your family and you all gain when your association has strength.

The Basic Limitations of Operations Research in Industry

By George S. Odiorne*

Director, Intra-Company Management Program, American Management Association

Operations research is such a new and ingenious engineering technique that we quite naturally look for its weaknesses. Yet this testing process, looking for basic flaws in structure and application, is entirely necessary if operations research is to stand the tests of time and rigorous use and overcome formidable opposition and indifference. It is in this light that the following observations are suggested. There is no questioning that OR is potentially valuable in research, engineering, production, marketing, and other special areas. It can further be accepted as a truism that in making these activities more efficient, OR helps management achieve its goal. Despite these, there is some doubt that the future looks rosy for OR as a tool or method *of* general management, at least until such time as it overcomes some of the conflicting and confusing aspects in basic principles which now characterize it.

The thesis of this article is:

1. That Operations Research is an ingenious and highly useful tool to supplement and strengthen the techniques of engineering, marketing, accounting, and other specialized technical areas.
2. It is suggested that there are some limitations upon Operations Research as a "Tool *of* Management", a label which is widely attached to it.
3. That it is casuistry to impute into OR sufficient capacity to call it *a way of managing*.

Limitations stem from some of the basic assumptions, both scientific and managerial, upon which Operations Research scientists apply their talents. It's at this assumption level, the jugular vein of OR, which we must probe if we are to discover what can be expected of it, and what cannot be expected of it.

As a tool of engineering or other applied sciences, in which the advantages of quantification of data are obvious, there can be no quarrel. It not only works well, it produces some startling benefits.

OR as a "tool *of* management" is stretching our definitions rather thin. More realistically it is "a tool of a specialist who applies his technical knowledge under managerial direction." It is not a tool *of* the manager himself. He designs no models, derives no formulae, makes no experimental studies, but rather directs the expert whose tool is OR. In this sense OR is a management tool in the same sense that everything that takes place, every machine, every material, every process, and every person at work is a tool of management. Information supplied by OR, just as information supplied by accountants, actuaries, lawyers, public relations counsellors or stooges must all fall within the same category. Many thoughtful OR scientists clearly see their role as professional contributors to the business goals. A considerable number, however, have enlarged its ambit of operations through methods that are more reminiscent of the book "How to Succeed in Business without Actually Trying" than the objectivity and dedication of the professional scientist. Operations Research is an exciting and promising tool for any firm. It is not a readily adopted set of management procedures which any administrator can easily acquire and use regularly in the way he uses skill in communicating, ability to motivate people, or skill in integrating diverse groups of people into effective working teams. It isn't even easy to acquire a subordinate who can use the techniques with skill and imagination.

The Assumptions of OR

More importantly than any defects in its application, there are some fundamental assumptions in OR which must be critically examined. These assumptions are not all clearly agreed upon by the technicians of OR, so it might be well to list a few of them.

1. Operations Research is the application of rational methods to the solution of complex problems developing out of action situations. By this is meant usually that "rational" is equivalent to mathematical, statistical, measurable, methods (or otherwise) subject to scientific classification as used in the natural sciences.

2. The problems of managing a business are subject to such rational treatment. This comes about because business operations are analogous to other processes of nature. There isn't total agreement on exactly which natural process business operations resemble however. One authority suggests that business may be treated in the same way as a biological organism—with OR as "business medicine". Still another thinker in the field suggests that business is like thermodynamics, and obeys the second law of entropy, with OR as a means of bringing order to disordered situations. A third suggests that business in many respects obeys the laws of physics, especially electronics and electronic circuitry. Such terms as "feedback" in general use owe their origin to this.

3. Operations researchers, as scientists studying business assume a basic nature of business; and also, although less often

* The views expressed are those of the author and do not represent an official position of American Management Association.

discussed, they have a philosophy of science. The predominant philosophy of science held by most OR men is one which is sometimes identified as "positivism." As positivists they assume any scientific system as a hierarchy in the form of a pyramid. At the base are the observed facts. Next level above them are simple laws that connect them, a few facts at a time. At the next higher level are general laws which connect these laws. Finally above all are a few grand generalizations which connect these tertiary level laws. In the natural sciences these abstract concepts are the theories of biological organizers, the electron spin, or the wave function. In OR as applied to management decision-making these assumptions are; that business organization is obedient to the laws of thermodynamics; or, that business is analogous to a biological organism; or, that business communication is analogous to electronic circuitry. The positivist sees these higher level abstractions as a shorthand for the underlying facts and nothing more. This school of thought, which has wide influence among OR men has been widely influenced by Percy Bridgeman. They accept tacitly the statement of Bertrand Russell that wherever possible logical constructions are to be substituted for inferred entities. OR then becomes more than an investigation of factual data for decision making. The resultant mathematical model from an OR study to the positivist is the summarization of business; *it is the business!*

How Sound are These Assumptions?

Once you have accepted the basic assumptions, heuristic principles, definitional assumptions, and useful fictions of the Operations Researcher he is on unassailable ground. From this point forward he constructs a logical structure of mathematical logic which is unquestionable. (Providing that his arithmetic is correct.) Furthermore, for most purposes, the average businessman remembers too little of his calculus to even follow the OR man's cerebrations, let alone question them. The important step then comes back at the point at which he looks criticallly at the assumptions, a step which is open to even a millionaire, because the manager in this area of basic assumptions about the fundamental nature of business is on equal or superior footing with the Operations Researcher. Even on the sacrosanct ground of philosophies of science, the businessman with training as a social scientist who is intelligent and observant speaks with equal authority with the mathematician or engineer, for if truth be known—this is no-man's land which is still subject to some disagreement.

Let's look briefly at some of the weaknesses in the philosophy of science which predominates among the OR experts—scientific positivism. Some mathematical philosophers such as J. Bronowski, R. B. Braithwaite, and the late F. P. Ramsey have pointed up some shortcomings of logical positivism as an attitude toward science. Of this positivist attitude Bronowski says:

> It is the right attitude in a science which is closed; it is hopelessly the wrong view when a science is still growing. For a logical construction which has been made to contain only the existing facts and relations cannot accommodate new relations . . . the concepts of a growing science must be richer and more pliable than any logical construction from the sum of its known facts.

Still another shortcoming of the assumptional area which underlies operations research is the meaning assigned to the term probability by most OR scientists. What does probability mean? How can we define the probability of a belief, a hunch, or a proposition, as well as the prediction of an event? Before OR can be adopted as a model of decision making in many areas of management it must more logically define the degree to which their rational decisions or laws of management bring order into the jungle of intuition, emotion, and reasoning by experienced hunch. At present all we can rely on from OR is that if we make generalizations on how a system has worked before, it is rational to assume that it will work again. Certainly we don't need scientists to tell managers this. Humans learn this from the time they are three years of age, until they become mathematical economists and human behavior is based in large part upon it. While the close scrutiny which OR makes available may define relationships more closely, and develop generalizations along lines of probability and linear relationships which are obscure to the naked eye, it marks a limitation upon OR as a top management decision-making tool. For based on the functions it can actually perform and contribute to general management it might rank in the industrial hierarchy well below cost accounting or Industrial Engineering in the rank and compensation of its practitioners who insist upon entering the market place with their wares. In view of the "overselling" which has characterized much of OR, it seems germane to suggest that the time is propitious for a more or less orderly retreat of OR back to the college laboratory, engineering research lab, or domain of basic mathematical research before emerging with procedures which are overmatched with the problems it is often pretentious enough to "solve".

OR as a Management Method

Dr. Simon Ramo in a speech before the American Rocket Society at Princeton last year declared that the manager of the future must be a systems engineer, who will manage the enterprise of the future surrounded by a subordinate corps of systems engineers. This Veblenian philosophy, evocative of the "soviet of engineers" has struck a responsive chord with a coterie of engineer-managers, and is worthy of some serious consideration by managers, and all thoughtful citizens of a free society. Russell L. Ackoff in *Management Science* published a widely discussed article suggesting that management will become "automatic" in the future through the application of mathematical decision making, abetted by the computer. These are the ultimate conclusions of scientific logical positivists armed with certain fundamental assumptions about the nature of business managements in business today, as well as many of the traditions of a free society. Tacitly it places OR in a category of having a monopoly over logical processes in business decision making. What is implied is not that present managers have to change, but that they must abdicate. Presumably this is to be done voluntarily.

Yet in assuming that the business firm obeys the laws of biological organisms, of thermodynamics, of physics, or of mathematical probability, the OR scientist is arriving at a generalization which will not stand up even under his own rules for scientific logic. In positivist logical science, each

generalization is built up in layers from the raw facts through successive connections of the lower layers in the form of laws. This structure is perfectly acceptable for what Bronowski called "closed sciences", because each generalization can be reversed and tracked back down through the layers for confirmation with the basic facts which remain unchanged. We know that the concepts have meaning and the laws are true because the deduced facts are verifiable. This is untrue in sufficient instances in business to cause a true scientist to abandon the concepts. In science we can never be sure that we are right in accepting a law, we can only be sure that we must reject it when one single instance contradicts it. The use of provisional definitions such as "8 out of 10" to the scientist means that he cannot even reject the law, any more than he can accept it.

The impact of charismatic leadership upon decisions, the apathy, irrationality and sentiment of people, the forces of ethics, and social values, political relationships, and all of the fuzzy and often wrongheaded but aggressively implemented decisions in business require a new approach entirely to the problems of measuring probability in these areas. The basic assumptions of choosing a suitable analogy of business structure by the OR scientists are likewise on quite shaky ground due to these shifting and growing forces. We must conclude that OR is simply another method which can be used profitably by companies within the context of some special area, such as the Industrial Engineering function, or in other areas of closed knowledge. This is a far cry from the exalted status which is claimed for it by some of its more opportunistic adherents, not that Industrial Engineering is a slight nor insignificant contributor to our industrial system by any means. OR's potential as a professional contribution to our standard of living and increased efficiency is enormous. It is bordering on casuistry to suggest that it is more than that. As Fayol pointed out many years ago, *administration* is an aspect of doing business that is distinct from the technical, commercial, financial, accounting, and security functions. To attempt to absorb administration into the technical function is a disservice to both.

Suggestions as to an analogy of the governing forces in business is an often harmless and sometimes helpful process. We learn something about business management in considering the useful fiction that it obeys the laws of thermodynamics, or physics. We might learn as much by considering it as drama, for example, having the basic ingredients which Burke describes as Act, Scene, Agent, Agency, Purpose. Considered in this light we can study more intelligently what people are doing and why they are doing it with certain objects in a certain situation, but not by mathematical methods. Armed with some knowledge of the basic forms of thought which are in accord with the nature of the world as all men experience it in all human behavior, we have a useful tool for understanding business. It might be closer to the truth to say that the tools of social investigation have not yet been devised to crystallize the unique nature of our industrial system. Certainly, by the very standards with which the scientist must evaluate his own work, the Operations Researcher has not yet developed much more than exciting and extremely fruitful techniques for the Industrial Engineer or specialist of the future.

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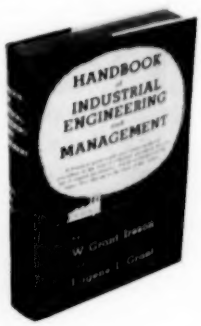

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By A. W. Swan

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There is a fundamental difference between an Operations Research Department as it exists in a Ministry or in a nationalized industry and in an industrial company. In a Government or semi-Government organization, an Operations Research Department is set up by decree; and although there may not be an instruction that all concerned must co-operate, it is not necessary for the Operations Research Department to prove its success financially or otherwise. In an industrial company an Operations Research Department does have to prove itself by results, not perhaps financial, but in improvement of practice or in more complete control by management. This fundamental difference means that in practice it is a sound policy for an industrial Operations Research Department to start modestly, if possible have one or two resounding successes of a practical character early in its life, and then build up from that point. From many examples which could be taken, an interesting one is that of the statistical sampling and Quality Control Chart scheme for hot rolled bar which was put in at Steel, Peech and Tozer Ltd.'s branch of the United Steel Companies during 1946 and 1947. This was their first effort in Operations Research and it was so successful financially and otherwise that the result was the formation of an Operational Research Department at Steel, Peech and Tozer Ltd., which has been functioning successfully ever since.

Terms of Reference

The Operations Research Department in an industrial firm is essentially an internal consultancy helping management to solve any type of problem which may occur. Its work, therefore, may impinge on that of the Economics Section, the Sales Department, the Production Department, Research, Engineering (with special reference to Maintenance), Work-Study, and Organization and Methods. It might be thought that there is some overlap between Operations Research and Work-Study on the one hand and Organization and Methods on the other. As far at Work-Study is concerned there may sometimes be an overlap; but in general, Work-Study is a continuing function dealing with time-study and method-study, with particular reference to the setting up of rates of payment and the improvement of production, whereas Operations Research has essentially an investigating function doing one job at a time. Organization and Methods, as normally defined, deals with office procedures, the designing of forms, etc., and again is not what is normally understood as Operations Research. The Operational Research Department, whose working is described in this paper, has on several occasions assisted the Work-Study Department in the same company and is involved, as will be shown, along with the Organization and Methods people on a job to which it makes its own characteristic contribution.

There need never be any feeling of competition between a "permanent" department of a company and the Operations Research Department since the latter's function is essentially to make inquiries, which will lead to recommendations that will be given to the operating department concerned to put into effect. Since the operating department is being helped and there is no feeling that jobs are in peril, cooperation is, or should be, easy to obtain. The question of possible censure on a department at the end of an investigation is more difficult. The Operations Research Department has to preserve its integrity, and may produce answers that are unpleasant to the permanent department concerned. This matter can be solved with tact.

Staff

Since the range of Operations Research activities as defined above may be extremely wide, it is impossible for there to be an expert in every branch of the organization's activities within an industrial Operations Research Department. It is, therefore, necessary for practical reasons as well as for sound psychological reasons to adopt the team method as standard practice. One or more members of the Operations Research Department form a team with one or more members of the operating department which is being assisted while an investigation is under way. In building up an Operations Research Department's staff, therefore, it is not necessary or even advisable to try to have too many members who are expert in the organization's activities. The actual staff in the Operational Research Department of a company which manufactures rayon and is, therefore, a chemical and textile organization, is as follows:

Head	Engineer-Statistician
Deputy Head	Statistician
Men Technical Assistants	Physicist-Statistician
Two Women Statisticians	Mathematician
Two Women Computers	Chemist being trained as a Statistician
Secretary	

All the members of the above staff who had little or no previous technical knowledge specific to the industry have acquired technical knowledge of the processes of their Company, but the fact that two of them were initially trained, one as a chemist and one as a physicist, and that the physicist had previous experience in the technology of the company before joining the Operational Research Department is very useful. The staff has been built up definitely to include both mathematical and technical knowledge, with a continuous exchange between the technological and the mathematical members so that the technologist becomes a statistician and vice-versa.

Selection of staff is carried out on the lines indicated, plus an insistance on easy personality, since the department is continuously mixing with management, submanagement, and workers in mill, laboratory and office, and an ability to handle situations of all kinds in a pleasant yet firm manner is essential.

Finding staff is extremely difficult. On every occasion within the last ten years when recruiting has been required it has been necessary to interview a large number of candidates, and it would appear that very few people have the requisite requirements for industrial Operations Research. There are those, for instance, who have admirable knowledge but who lack imagination; others who have confindence to the extent that would irritate the old hand in the mill.

There is no education at present for Operations Research as such. Engineering courses in Great Britain include the mathematics necessary for design, but little or no statistics and the statistical idea is essential in Operations Research. The same remarks apply to training in most other technologies. The applied mathematician who has training in statistics may be a good candidate if he is not too academic in thought. The danger of the mathematical statistician in Operations Research is that he may become so interested in the job that he forgets he is there primarily to obtain answers. Since there are very few ready-made Operations Research people to recruit, it is necessary to take into the department men, and in some cases, women, with either mathematical or statistical training, or technological training which has included sufficient mathematics to permit them to continue on into the more advanced stages, and then to train them within the department. This training is done partly by discussion with colleagues, partly by taking part with colleagues in actual jobs, partly by reading, and partly by attendance at and writing papers for meetings of the relevant societies, such as the Royal Statistical Society, the Operational Research Society the British Rayon Research Association, the Textile Institute, etc.

Methods Used

There has been a great deal of discussion and argument about the methods used in industrial Operations Research and also in Operations Research applied to military and other purposes. The fact is that the Operations Research worker has to use a battery of equipment which is extremely wide and he must be aware of every method that is available. Mathematics play a very important part in industrial Operations Research, and there has been a school of thought which insisted that Operations Research can only be done successfully by people with very advanced mathematical knowledge, so that Operations Research must necessarily be restricted to such people. It is interesting to note that in France the emphasis is entirely different. Practically all Operations Research workers in France (It is true there are not very many of them as yet.) are engineers and all the recruiting is being done from engineers. The instruction of these people is mainly by mathematical professors, and the equipment which they are being given is largely of a mathematical character. Nevertheless, the fact remains that their outlook is that of the engineer and the engineer's outlook is something special; he is always concerned with application of theory rather than in theory as such. We could learn something in this country, and perhaps in America, from this attitude.

In industrial Operations Research the job can be said to be made up of five parts:

1. Inception and Planning
2. Collection of information
3. Analysis
4. Report
5. Follow-up

The actual techniques used, whether statistical, some other mathematical method such as linear programming, plain graphical, or ordinary common sense, can only come into stage 3, the analysis; and this may not be the most important of the stages.

The really important and difficult part of an Industrial Operations Research job is in successfully dealing with the first stages, and particularly in connection with the human aspect and in securing correct and suitable information. It has been said earlier in this paper that the team method is essential, and it might be thought that this is but common sense. Nevertheless, it is a method which is still very rare in an ordinary industrial company because an ordinary company is divided into sections, and within these sections the people employed are kept fully occupied. An accountant, for example, does not normally have very much to do with the research chemists; and the engineers have little contact with the sales force, and so on. While the "Working Party" method is not new to industry it has been up to the present applied on the whole to specific jobs and the Operations Research method of using a team as standard practice for every job is new.

The planning stage of an Operations Research job is far more important than has been recognized in the literature, 90% of which is devoted to analytical techniques. The preliminary stages before any analytical work is done may be quite lengthy and involve technical study and organizational work of a fairly considerable character. A good example of this job was a job which was done at Workington, where the problem was to find the reasons for

defects in rails, and if possible to recommend procedures which would reduce the percentage of defectives. This job eventually proved to be a very massive statistical analysis of some 80 factors in the process of rolling rails, beginning with the characteristics of the mixer iron right through to the method of cooling, etc., of the finished rail. Three of the factors were shown to be the principal causes of trouble (three needles in the haystack), and concentration on these three factors reduced defectives by 50%. Prior, however, to the actual statistical analysis it was necessary to make an intensive study of the technical aspects of the problem and of the information system, which led to suggestions in regard to the taking of temperatures at rolling, etc., and to re-organized arrangements for collecting information from the plant. This latter included the designing of a new case history sheet with the co-operation of the works office, a job which was in itself quite an undertaking. It was also necessary to check whether information was reliable and in this respect also reforms had to be carried out, particularly in regard to the final identification stamping of rails. It was only when these preliminary arrangements regarding completeness and reliability of information had been completed that it was possible to begin to collect the data and eventually to make the analysis.

Working Out a Plan

The following actual example of the process of working out a plan for a job illustrates a number of points in current practice in industrial Operations Research. It illustrates, for instance, that Operations Research and Organization and Methods are not the same, but that the characteristic O. R. approach may be a great help when applied to an O. & M. job. It also illustrates that it is not possible to divide Operations Research methods into a number of water-tight compartments, statistics, linear programming, etc., but that any situation is examined with a free mind, one or more of the methods available being used according to circumstances.

The Operational Research Department was asked to assist in connection with the conversion of production planning to computer application. In this instance, the first step was to make a straightforward Organization and Methods survey setting out the current procedure and indicating how a computer might be applied to this procedure. Although the present method functions with reasonable success, the Operations Research worker felt that an electronic computer, since it can scan in a few hours an enormous number of possible plans, would make it possible to make an optimizing survey which would otherwise be for practical reasons impossible. He then proceeded to think something on the following lines: "It would appear that we have a problem of balance between the amount of stock and the length of run on the machines. We can have alternatively a short cycle production plan in which the various types of product are put in turn on the machine for relatively short runs or a long-term plan in which the runs would be much longer. The short-term run would be associated with relatively small stocks, but there would be more disturbance brought about by changes in machine settings, while in the long-term project the position would be reversed; there would be larger stocks and less disturbance. Let us, therefore, examine the problem in this light, setting up suitable mathematical models, with particular reference to the computer's potential capacity for examining a large amount of alternative solutions."

The above story is typical of what happens in an industrial Operations Research job. The length and complexity of the preliminary stages may vary, but the pattern is always there.

Let us now consider the inception of a job from the human point of view. There have been two schools of thought in regard to the inception of Operations Research jobs, that the Operations Research Department should suggest jobs to the management and that the management should suggest jobs to the Operations Research people. Both methods are naturally used in practice but it is definitely preferable that the bulk of the jobs should be as the result of requests for help. The O. R. Department should not be a reforming or investigating department which sets out to put everything right. Members of an industrial Operations Research Department are bound to have ideas of their own, and these will lead to jobs, but the healthy state is when the department is being overwhelmed by requests for assistance. It is true that the latter condition almost inevitably leads to a certain amount of lopsidedness in the work, since an Operations Research Department becomes known first to parts of the organization to which it belongs and later on to other parts, and requests for help will show this effect. Patience, therefore, is needed during the first few years of an Operations Research Department's inception and an acceptance of this lack of symmetry in types of job. Satisfied "customers" pass on the news that the Operations Research Department is helpful, and the scope enlarges. After six years of existence in a large rayon manufacturing company the O. R. Department still has no requests from quite large sections of the organization, but it is kept so extremely busy by others that it is prepared to wait rather than to thrust itself forward or to go cap-in-hand to those from whom requests have not yet been received.

The usual origin of a "request" type of job, and this statement is based on experience with a steel company as well as in the rayon industry, is by telephone or a visit by the person who wishes help; and the request is as a rule in very general terms, something on the lines of the following: "We have a problem about so-and-so, can you help us?" The next step is a discussion in the office of the executive who has made the request. At this discussion the problem becomes clearer, and it is then possible to begin to plan, and to form the team consisting of one or more from the Operations Research Department and one or more nominated by the executive who has made the request.

Next comes the working out of the method to be adopted which covers the information available and to be obtained, and the method by which this is to be analyzed. In the Operational Research Department whose work is being described, 90% of the analyses have been made by statistical methods. This does not, however, prove that statistics is the only, or the best, means of dealing with these problems. It only shows that the Operations Research men in question think most naturally in statistical terms. A certain well-known British O. R. authority would in all probability tackle the same problems by setting up in his mind models in terms of crystallography or some other physical concept and he would be equally successful.

The form of the information available and to be made available is of fundamental importance. The industrial Operations Research worker seldom finds that the information available is in the form he needs it, and whether he proposes to use works or office data or arrange for a special experiment, careful planning will be needed.

On the personal side he must be careful about what may be called protocol. If, for instance, more than one mill is concerned in the problem and data are to be secured from each mill, he must be careful to see that the manager in each case is kept fully aware of all that is happening and is consulted in regard to any visits. If separate sections of an organization, such, for instance, as Sales, Research, Accounting, etc., are involved, he must see to it that the various executives are consulted and kept informed.

The above may seem trivial and even, perhaps, absurd; but this is far from being the case. The courtesies of business have not grown up by accident and they deserve full consideration. Without such consideration an Operations Research Department will fail. Cooperation cannot be obtained from a man who is offended.

Planning may be divided into two sections, long-term or strategical and short-term or tactical. Long-term planning begins, as has been indicated with discussions with the executives who have put the problem, and at this stage the question of data has to be decided with particular reference to whether works data will be adequate or whether a planned experiment must be made. The statistician always prefers the planned experiment; and if he is lucky enough to be brought in at the pilot stage of a process, a planned experiment may be possible. If, however, he is dealing, as he usually is, with a process which has settled down through trial and error to a reasonably satisfactory level, he will find that the planned experiment with its fairly drastic variations on normal practice will be unacceptable to the production heads. If, for example, one were examining technical characteristics of the production of a particular kind of rayon filament, the O. R. worker might wish to have an experiment in which quite a number of factors were varied over a suitable length of time, spinning speed, acid concentration, etc. He would find, however, that the actual range of variation possible in view of production commitments would be relatively slight, and that a planned experiment in the full sense could not be undertaken.

In this connection, Dr. Box's "Steepest Ascent" method provides hope as giving a statistical experimental method which is acceptable from the mathematical point of view and which does not upset production and is therefore acceptable to production heads.

An important stage in long-term production planning is the assigning of an O. R. worker to the job, and in this connection there arises the question as to how many jobs the various members of the Operations Research Department should have on hand simultaneously. There are two aspects to this problem, the practical and the psychological. From the practical point of view one has to remember that an Operations Research job consists of several fairly well defined stages: initiation, collection of data, analysis, computing and report. The worker is concerned in the first stage in the planning of the job, but when it comes to collection of data whether experimental or works data, he will have to wait while the data accumulate. This may be a period of from a few days to several weeks. When the data arrive, the worker will be busy on analysis. This generally leads to computation which is passed on to the computing section of the department. When the computing is completed, the Operations Research worker again comes into the picture to write the report. When the report is completed, he submits it to the executive who has asked the question, and waits for a reply. When clear, the report is typed and issued.

It will be observed that in this process it is possible to be personally occupied on a specific job only for a relatively small proportion of the total time which that job requires. It is, therefore, evident that unless he is to be idle he will need to have more than one job on hand at a time.

There is also the psychological aspect. The worker has much hard and original thought to do, and very few people to turn to for help. It is, therefore, important that he be given assistance in regard to interest, and particularly to see that there is no danger of monotony leading to staleness. It is advisable from this point of view that the Operations Research worker have two, three, or more jobs at one time, the number depending upon the practical considerations given above. With an arrangement of this character, a balance can be maintained between the various sections of a job; and the Operations Research worker can feel he is fully yet sensibly occupied.

It follows, for both practical and psychological reasons, that the worker in an industrial department will have two, or three, perhaps more jobs on hand at the same time. How is he to plan this distribution of work? A fairly obvious way is to see what proportion of time on each job is likely to call for his personal attention. If this is say one-quarter and he is to be completely occupied on jobs, he will take on four. This, however, is not sensible. The proper thing to do, in this instance, is for him to have three jobs and leave himself some time for reading and research thinking.

A system, such as that outlined above, calls for control if the department is of any size. This can be provided without resorting to complicated methods by the use of a Visible Card Index in box or book form as described below. The actual system described is in the form of a two-page book which contains sixty 5″ x 8″ cards, 30 per page, each card having a visible index along the lower edge. The right-hand page is devoted to jobs which are actually in progress and the left-hand page to jobs which have recently been completed but may lead to others, and to jobs which are temporarily in suspension. The method of use is simplicity itself. The body of the card serves as a diary of the job, one entry being made per week. The visible strip is divided into weeks and shows how the job has been and is progressing. There are four types of visible index signals. Yellow shows the date on which the job began. Blue indicates that the job is progressing satisfactorily. Red shows a delay inside the department caused possibly by congestion in the computing section. Green indicates a delay external to the department as in the collection of data or in obtaining a decision from the executive at one of the mills.

Once a week the schedule is brought up to date and examined by the head of the department.

Reports

The Reports of the Operations Research Department should be written always with a specific person in mind, namely the originator of the request for help. This may be the Managing Director, the Director of Research, a Mill Manager, an Office Manager, or a Technical Manager. In each case, there will be a slightly different approach. An amusing and actual example was one report on a technical matter which was written for a certain Dr. X., who was, as described by the Operations Research worker, a "simple soul". The report was written, therefore, in simple elementary terms. He was succeeded in his job, however, before the report was completed, by Dr. Y., a much more sophisticated person in mathematical matters, and the report was rewritten accordingly.

The emphasis in a report always, however, results from the fact that the main desire of whoever originated the request, however unsophisticated or sophisticated he may be, is to secure answers to certain practical questions. It is, therefore, standard practice in the reports of the particular Operations Research Department described to begin all reports with a summary containing the following sections: Object, Results, Recommendations. This summary is followed by a full description of the method employed and the results set out in full. Mathematical details are given in special appendices. The language used is as simple as possible, and jargon of the statistical or mathematical kind is not used except in the appendices.

The initial summary, it will be observed, includes a list of recommendations and this is standard practice. In earlier days it was thought by some that industrial Operations Research was to some extent akin to pure research, and that it was sufficient to set out results without giving recommendations (see Morse and Kimball's book, for example). This view, however, is not accepted by the O. R. Department concerned which is not considered to have completed its service until it has given definite recommendations for action. These recommendations are for use in the permanent department which is being helped by the heads of that department and not by an Operations Research worker.

Analysis of Actual Jobs

The actual program, which includes analytical methods as one step of many, varies considerably from job to job. Let us, as a matter of practical interest, look in some detail at some of the jobs carried out by an industrial Operations Research Department.

Machine Interference

Origin

This job arose from a request by the Work Study Department to help them in improving the workers' "share" in coming and other similar operations, particularly from the point of view of machine interference.

Preliminary Planning, Team, Data

The first stage was an intensive study of the literature on machine interference with particular reference to the Wright, Benson and Cox, and Asheroft formulae. It was decided that it would be necessary to take extensive time studies to a particular pattern, the actual studies to be made by skilled time study men, and that these would provide data which could then be analyzed.

The team consisted of one member of the Operational Research Department and a varied number of time study men.

Data were obtained from the time studies mentioned above.

Analysis and Computation

The analytical methods used were fairly straightforward in the statistical sense, mainly Analysis of Variance, the t Test, etc., but in addition it was necessary to work out tables for the Asheroft formulae beyond the published limits. The computation was massive particularly because of the Asheroft calculations.

Reports and Recommendations

The report showed that some of the known formulae were applicable under certain conditions and others under certain other conditions and how to use the formulae to the best advantage; also that the information obtained should be put to use in improved practice. A Joint Committee of the Work Study Department and the Operational Research Department was set up to provide a manual and put these recommendations into effect.

Twisting Production

Origin

The origin was a request from a Twisting Department to see what measures could be taken to increase its production with particular reference to increasing the length of runs of products on machines.

Preliminary Planning, Team, Data

After careful consideration the method adopted was to simulate alternative systems of production using the so-called Monte Carlo method, and estimate the gains that would accrue if a rationalization program were adopted.

The team consisted of two members of the Operational Re-

search Department and heads of departments at the mill as required for consultation.

There were relatively little actual data available, and it became a question of creating synthetic data by the Monte-Carlo method.

Analysis, Computation and Report

The first stage was a pilot run, using hand punched cards to estimate the potential financial gains if a full scale inquiry were undertaken. These were indicated to be of a very substantial order. The next stage was to make a full scale inquiry using an electronic computer on a service basis. The job is in progress at the time of writing.

Valve Maintenance

Origin

A request was made from the engineering side of the company to the Operational Research Department for data on the effective life of a certain proprietory valve used in large quantities in the manufacture of viscose. This was put on a formal basis by reference to the chief engineer.

Preliminary Planning, Team, Data

With the cooperation of the management in two mills which use large quantities of these valves, a survey was carried out. This was followed by joint consultation with the valve manufacturing company resulting in several constructive suggestions. Again with the cooperation of one of the mill managers, a full-scale trial has been planned and will give quantitative information regarding optimum valve life.

It was found that data were very scanty and one of the first results of the inquiry was to make very strong recommendations that better records be kept in a particular form of the life of the valves in service.

Analysis, Computation and Report

The job is still in progress.

Time Study and Rating

Origin

The origin of this inquiry was an interest in time-study by one of the Operations Research workers combined with a certain skepticism about the validity of the claims made for rating. The inquiry was an analysis of the relationship of observed times and rated times in a number of routine time-studies taken at different mills, with a view to determining to what extent rating is efficient and the various factors which affect the time-study man's efficiency in this respect.

Preliminary Planning, Team, Data

With the cooperation of the Work-Study Department a number of recorded time-studies were obtained for analysis.

Analysis, Computation and Report

The first stage of the analysis consisted of examination of the data provided regarding time-studies, mainly through distribution curves of observed times, rated times, and ratings. A further stage was regression analysis of observed times against rating. There was little computation of the ordinary kind, but a considerable amount of drawing of regression scatter diagrams and frequency distribution curves. From the above, various conclusions were drawn in regard to the efficiency and otherwise of the rating system, with suggestions for improvement.

Weavability Trials

Origin

A technical member of the Processing Division asked for assistance to design and analyze trials to estimate the comparative merits of different types of sizes in warp weavability trials. ("Size" is used in the textile sense to describe coating material applied to thread to improve weavability.)

Preliminary Planning, Team and Data

There were discussions with the originator of the problem who made up a team with a member of the Operational Research Department.

The data were provided by the experiments.

Analysis, Computation and Report

Analysis of Variance and associated techniques were used. In the Report attention was drawn to the sizes with the best performance. This is a continuous job leading to successive suggestions for improvement.

Summary

An industrial Operations Research Department has to prove its worth in practical results, by reducing costs, by improving quality, or by bringing about simpler and better methods of management. It is concerned with long-term fundamental investigations and with bread-and-butter problems. It is not concerned with pure research except in the development of its own techniques.

Operations Research in industry works as an internal consultancy helping other departments which require the special kind of help which an Operations Research Department can give or that are too busy to be able to investigate their own jobs fully. Its prime purpose is to provide practical answers to practical questions.

As a consultancy an industrial Operations Research Department has no executive power and no continuous jobs. It hands back results and recommendations to the department which asked for help so that this department can put them into effect. The importance of these characteristics cannot be overemphasized since, if they are fully understood, they will prevent rivalry or difficulty between the Operations Research Department and the operating departments in the company which asked for help.

An industrial Operations Research Department requires for its staff both those who have a mathematical background and a special knowledge of some technology such as engineering, physics, or chemistry, and mathematicians trained as such. An essential ingredient in all members of the Operations Research Department, whatever their training may be, is that they are interested in and can be friends with colleagues in all other departments of the company for which they work and at all levels of importance.

A special contribution of Operations Research to industry is the use of the combined working party on a regular basis, the working party cutting across established functional divisions if need be.

Planning is of paramount importance in industrial O. R. and within planning the most important factor is the personal one in which smooth working with one or more operating departments is assured.

Statistical Procedures in Standards Auditing

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One of the big problems in all wage incentive plans is the maintenance of accurate standards over a period of years.

At Lukens, we have a planned program for maintaining the equity of our production standards. This program comprises several different controls, the most effective of which is a periodic audit of all our premium pay plans, now numbering over a hundred. Naturally, with such a volume of incentive plans to be covered, it has been difficult to complete the audit cycle as often as we would like. An approximate two year frequency of review is our ultimate goal for this phase. To keep these audits unbiased, and likewise to maintain a consistent viewpoint of standard throughout our plant, this function is handled by a small group reporting directly to the Manager of Industrial Engineering.

As our original standards have been set by time study, this review or audit consequently, is made using the same procedure. Customarily, in these audits, we have been nearly as comprehensive and thorough as we were in developing the standards initially. As such a procedure takes considerable time, we were confronted with the problem of keeping up with a constantly broadening schedule. It was with this problem in mind, of how best to accelerate our auditing procedure, that we began to investigate statistical techniques. In order to prove effective, these statistical techniques would have to accomplish two objectives:

1. They would have to reduce the overall time spent in making the audit.
2. They would have to provide a degree of reliability comparable to the more comprehensive procedures.

The Statistical Problem

The foregoing represents the auditing problem, i.e., how could audit time per investigation be reduced (so as to permit faster coverage) while maintaining sufficient reliability in the results of the method employed? The statistical problem is one of hypothesis testing based on sampling theory and contains the following elements:

1. An underlying "true" situation exists.
   a. The standard validly covers present performance.
   b. The standard does not validly cover present performance.
2. Using sampling, a certain number of observations will be taken which will be used to test the above hypotheses.
3. The auditor can make two errors (in statistical language errors of the first and second kind) in testing hypotheses with sample data.
   a. He can say that a difference exists between prevailing standard and true current operation, when, in fact, no difference does exist (error of the first kind or alpha).
   b. He can say that a difference does not exist between prevailing standard true current operation, when, in fact, a difference does exist (error of the second kind or beta).

The Setting of the Problem

In our particular operations most standards are set up in relation to certain characteristics of the product, e.g., weight, diameter, gauge, surface area, etc. Inasmuch as the nature of our business is largely job-shop, the tables are designed to cover as wide a variation in product mix as practicable. Table 1 is a typical example from one of our standards bulletins:

TABLE 1

Flatten Carbon Steel Backing Plates—83 Press

Plate Area (Sq. In.)	Std. Hrs. per Piece	Plate Area (Sq. In.)	Std. Hrs. per Piece
1,000	.14	6,000	.24
1,500	.15	6,500	.25
2,000	.16	7,000	.26
2,500	.17	7,500	.27
3,000	.18	8,000	.28
3,500	.19	8,500	.29
4,000	.20	9,000	.30
4,500	.21	9,500	.31
5,000	.22	10,000	.32
5,500	.23		

As can be noted from the table, the relationship is linear within the range covered and amounts to a .02 standard hour increase per 1000 square inch increase in plate area.

"Proving out" the accuracy of tables such as these can be a perplexing problem. The auditor can find, for example, that the lower section of the table is loose and the upper section tight so that, overall, the two may tend to balance out. Although situations such as these can arise, the audit group must always weigh the cost needed for

greater accuracy against the pay-off derived from this finer degree of accuracy. From the standpoint of departmental policy, "accuracy" pertains to the average accuracy of the total table and not to that of each individual standard.

The Method of Paired Differences

For the tests to be discussed it is assumed that the sample observations (time studies) are taken at random and are representative of the normal universe under study. Although these conditions are often difficult to meet in practice, our preliminary checks indicate that these requirements can be approximated. The procedure thus is conducted as follows:

1. The standards auditor proceeds to take a representative sample of the work flow covered by the standards under study. This sample is checked by product mix characteristics prior to audit so as to achieve the desired representativeness.
2. The time study data is then converted into standard hours per piece.
3. Paired differences of sample times minus the present standard times are computed.
4. These differences are subjected to a statistical "t" test.
5. Based upon the results of this test, the auditor decides within certain error risks to:
   (a) Accept hypothesis that standard is adequate coverage of present performance.
   (b) Reject hypothesis that standard is adequate coverage of present performance.
   (c) Take more observations until (a) or (b) is finally reached.
6. When conclusions have been reached from these tests, the results and accompanying recommendations are submitted in writing to the Operating Superintendent and to the Zone Industrial Engineer responsible for the particular incentive plan. If corrections are necessary, the zone engineer then has sufficient additional studies taken to revise the production standards.

An Example

Referring again to Table 1, we assume that the Standards Auditor takes current studies on the backing plate operation, yielding the following data:

TABLE 2

Sample Results on Time to Flatten Carbon Steel Backing Plates—#3 Press

Plate Area Sq. In.	Std. Hours per Piece
1,500	.16; .13
2,000	.14; .16
3,500	.17; .18; .19
6,000	.21; .22; .25
8,500	.27; .31
9,000	.27; .29
10,000	.33

Does the sample evidence indicate that the present standard validity covers true current operation? First, a risk level must be stated; suppose an alpha level of .05 is chosen. This means that if the hypothesis (universe paired difference mean equals zero) were indeed true, the employment of this test would in the long run lead to a rejection of this hypothesis 5 times out of 100. This risk of rejection of a true hypothesis is an error of the first kind or alpha.

The following computations are made:

TABLE 3

Std. Hrs./Piece		(D)	(D^2)
Sample Results	Present Standard	Paired Differences	Paired Differences Squared
.16	.15	+.01	.0001
.13	.15	−.02	.0004
.14	.16	−.02	.0004
.16	.16	.00	.0000
.17	.19	−.02	.0004
.18	.19	−.01	.0001
.19	.19	.00	.0000
.21	.24	−.03	.0009
.22	.24	−.02	.0004
.25	.24	+.01	.0001
.27	.29	−.02	.0004
.31	.29	+.02	.0004
.27	.30	−.03	.0009
.29	.30	−.01	.0001
.33	.32	+.01	.0001
		$\Sigma D = -.13$	$\Sigma D^2 = .0047$

1. The sum of the paired differences (sample results minus present standard).
2. The sum of the squares of these paired differences. See Table 3.
3. The determination of the standard deviation S_D of the sample proceeds as follows:

$$S_D = \sqrt{\frac{\Sigma D^2}{n-1} - \frac{(\Sigma D)^2}{n(n-1)}}$$

where n = sample size
D = Paired difference

The sum of the 15 paired differences and paired differences squared (from Table 3) are −.13 and .0047 respectively.

Substituting in the formula above:

$$S_D = \sqrt{\frac{.0047}{14} - \frac{(.13)^2}{15(14)}} \qquad S_D = \sqrt{.0002552} \qquad S_D = .01598$$

4. The "t" test for the method of paired differences is as follows:

$$t = \frac{|\bar{D}|\sqrt{n}}{S_D} \qquad t = \frac{.00867\sqrt{15}}{.01598} \qquad t = 2.1013$$

where: $|\bar{D}|$ is the arithmetic mean of the paired differences without regard to algebraic sign (equal to .13 ÷ 15 or .00867)

Table 6 shows, for an alpha level of .05, the associated t values for respective $n - 1$ sample sizes. If computed t is less than or equal to tabular t, one accepts the hypothesis that the true paired difference mean equals zero; if computed t is greater than tabular t, one rejects this hypothesis. The tabular t in Table 6 for $n - 1$ sample size or 14 in this case is 2.1448. Since computed "t" is less than the tabular

t value, the auditor accepts the hypothesis that no difference exists or that the present standards are valid. He realizes, of course, that he may be accepting a false hypothesis, viz., the observed data may lead him to believe the underlying true mean difference is zero when actually it is not.

To gain some insight into what this beta error is, the auditor consults an operating characteristic curve (See Fig. 1). Suppose he desires to have the probability of committing a beta error no more than .10 when the population value is one standardized difference away from his hypothesized value. If the universe paired difference mean, for example, were | .016 | with a .016 (assumed) universe standard deviation how frequently would he accept the hypothesis of zero difference? Consulting the operating characteristic curve for $n = 15$ and standardized difference equal to one, he finds that the probability of erroneously accepting the hypothesis of zero difference is only .05, or well within his criterion. Had the probability exceeded .10 the auditor would have been forced to take more observations or change his risk criterion.

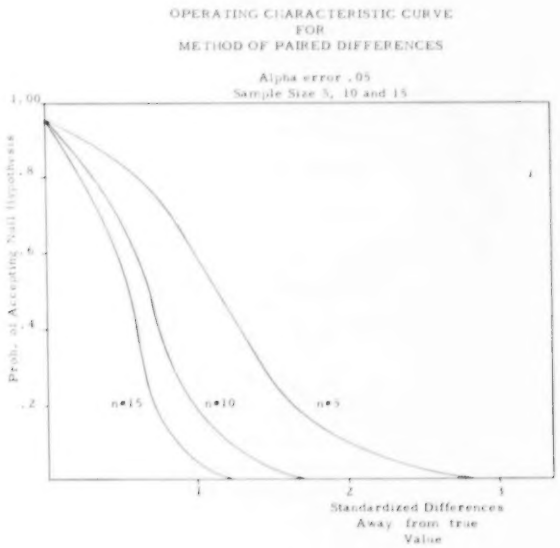

FIG. 1

As can be noted by the shape of the operating characteristic curve, small differences in the true situation versus the hypothesized one will lead to fairly high beta errors but for large differences this risk markedly declines which is in accord with what we would like a test to detect. The curve also points out the advantage of larger sample sizes in reducing the risk of an erroneous decision.

Sample Size Determination

In the example given, no mention was made of sample size determination required for the hypothesis tested. In practice, with given risk levels and knowledge of the population standard deviation, tables are available showing the sample size required (1). If no advance knowledge is available concerning the universe standard deviation, the auditor can take a small sample (eight to ten observations) so as to arrive at an estimated standard deviation of the universe which he can employ to obtain a crude estimate of the sample size needed.

TABLE 4

Sequential Paired Differences

Observation Number	Sample Results	Present Standard	Paired Difference
1	.12	.15	−.03
2	.20	.24	−.04
3	.27	.29	−.02
4	.19	.19	.00
5	.30	.31	−.01
6	.25	.30	−.05
7	.22	.26	−.04
8	.12	.15	−.03
9	.13	.18	−.05

Sequential Sampling

In cases where the underlying situation is assumed markedly different from the standard in use, the auditor may wish to forego using a fixed sampled size and carry through his analysis on a sequential basis. This procedure is particularly applicable in cases where the cost of taking observations is high.

An Example

To demonstrate how this procedure works, suppose that the auditor were to assemble a different set of observations on work covered by Table 1 which yielded the data, in sequence, shown in Table 4.

Further, let us assume that the auditor uses the risk levels of alpha .10 and beta .10 at one standard deviation. With this information, Table 5 is constructed and the last column (Col. 7) is plotted on Fig. 2.

TABLE 5

(1) Observation Number	(2) Paired Difference	(3) Paired Difference Squared	(4) Cumulative Col. (2)	(5) Cumulative Col. (3)	(6) $\sqrt{\text{Col. (5)}}$	(7) Col. (4) + Col. (6)
1	−.03	.0009				
2	−.04	.0016	−.07	.0025	.0500	−1.40
3	−.02	.0004	−.09	.0029	.0539	−1.67
4	.00	.0000	−.09	.0029	.0539	−1.67
5	−.01	.0001	−.10	.0030	.0548	−1.82
6	−.05	.0025	−.15	.0055	.0742	−2.02
7	−.04	.0016	−.19	.0071	.0843	−2.25
8	−.03	.0009	−.22	.0080	.0894	−2.46
9	−.05	.0025	−.27	.0105	.1035	−2.61

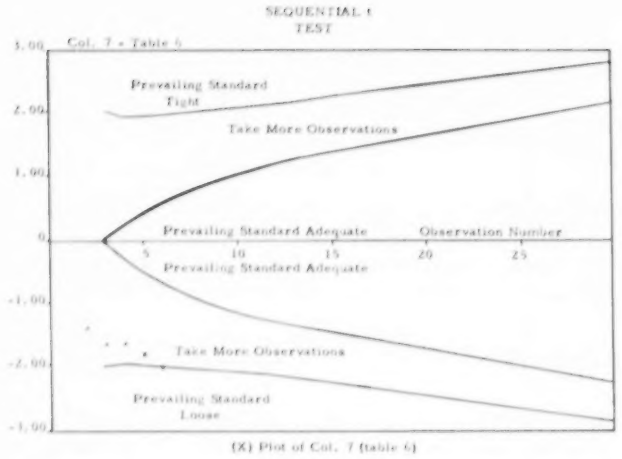

FIG. 2

In this instance, the sequential test (known as Barnard's Test—Reference 1) indicates that the hypothesis of no change would be rejected at observation number six which crosses the "loose" standard line. (See Fig. 2). In general the sequential test requires fewer observations to reach decisions than the fixed sample size test, but does require calculation after each observation.

Application and Conclusion

Both of the tests described above are relatively simple insofar as calculations are concerned and can be taught to the standards auditor in a minimum of time; their utility, of course, lies in the assistance and not replacement of his judgment; their success requires meeting the assumptions of representativeness and randomization in the sampling process itself.

We investigated these techniques at Lukens to meet a specific need: greater speed of auditing. Actually, they are still too new with us to make an accurate appraisal of their full possibilities. However, based on an estimate made by the man performing the standards auditing, he will save approximately 500 man hours of time study in our first year of application. As we gain experience with these new techniques and we step up the frequency of our audits, even greater savings in manpower can be anticipated for the future.

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(2) RUSSELL L. ACKOFF, Design of Social Research University of Chicago Press, 1953.

TABLE 6

Sample Size (n − 1)	Tabular t	Sample Size (n − 1)	Tabular t
5	2.5706	21	2.0796
6	2.4469	22	2.0739
7	2.3646	23	2.0687
8	2.3060	24	2.0639
9	2.2622	25	2.0595
10	2.2281	26	2.0555
11	2.2010	27	2.0518
12	2.1788	28	2.0484
13	2.1604	29	2.0452
14	2.1448	30	2.0423
15	2.1315	40	2.0211
16	2.1199	60	2.0003
17	2.1098	120	1.9799
18	2.1009	∞	1.9600
19	2.0930		
20	2.0860		

If computed "t" is less than or equal to tabular "t" for n−1 sample size, accept "null hypothesis"; otherwise, reject.

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Labor Looks at Automation*

By Jerome D. Schaller

Director of Public and Farm Relations, Minnesota AFL-CIO Federation of Labor

Automation is a subject which has interested the leading industrialists, labor leaders and governmental leaders in this country. Most of you are in a position where you understand the mechanical application of automation to an industry, and I am sure that most of you are in a far better position than I to realize the full value of automation to the business life of America.

For many months now the public relations department of the Minnesota AFL-CIO Federation of Labor has been collecting literature, special material and other data from various sources on this subject. It would seem to me after reading the material which has been prepared by outstanding people from all phases of American life on automation that there are many and varied opinions to the effects of automation on the American economy and the American way of life.

I would like to convey many of the ideas and thinking which is currently being expressed by leaders in labor, as well as leaders in business and government, on this subject.

George Meany, president of the AFL-CIO has said this about automation:

> Labor welcomes these technological changes. The new techniques offer promise of higher living standards for all, a greater leisure, and more pleasant working conditions.

Walter Reuther, chairman of the AFL-CIO Economic Policy Committee has said:

> We fully realize that the potential benefits of automation are great, if properly handled. If only a fraction of what technologists promise for the future is true, within a very few years automation can and should make possible a 4 day work week, longer vacation periods, opportunities for earlier retirement, as well as vast increases in our material standards of living.

Joseph A. Beirnie, who is president of the Communications Workers of America and an AFL-CIO vice president, has said:

> For ourselves, we welcome automation because we see in it a lever for higher wages, longer vacations, shorter hours, and, ultimately, greater security for ourselves and the American people.

In discussing automation, these American labor leaders have pointed out that labor has not met this age of progress with fear, but with hope. At the same time, however, they, perhaps more than anyone else, are conscious of the problems that automation will create for the working people of America. Mr. Nat Goldfinger, who is with the Research Department of the AFL-CIO, has been assigned the full-time task of watching the progress of automation throughout the United States, as well as working out the problems and the consequences of these new technological advances.

Perhaps for the record, we should stop for a moment and decide exactly what we feel automation is.

Automation vs Mechanization

In brief, labor feels that there are two factors involved in automation—a machine to do the work and an automatic brain to guide it.

Automation is not mechanization. Mechanization means replacing human *labor* by machine while automation is replacing human *control* by machines.

In other words, in mechanization a man thinks for the machine, in automation a machine thinks for a machine. In mechanization, the machine does the work but a man regulates it. In automation, a machine does the work but another machine regulates it.

Examples of Automation

Labor isn't concerned about automation for what it might bring. Labor is concerned about automation because automation is already here. I would like to cite some examples of automation that are already here.

The Ford Engine Plant in Cleveland has one machine to control a unit the length of a football field which performs 540 separate operations and turns out 100 engine blocks an hour. In this operation 41 men are now used instead of 117. As a matter of fact, one machine takes the iron, the sand, and ends up producing an engine block at the end of the line.

In Marcus Hook, Pennsylvania, one man literally has finger-tip control over an entire chemical plant. This may sound like a Rube Goldberg cartoon, but it is a down-to-earth reality.

In Chicago, two men in a radio plant assemble 1000 radios a day with automation. This used to require 200 men. In the oil industry, automation has advanced to the point where a handful of technicians can run an entire $40 million plant by remote control from a panel of instruments.

In some plants, the entire canning process including the manufacture of the cans and cartons is completely automatic.

Right here, Minneapolis Honeywell Company has

* Based on a presentation to the Minnesota Chapter, American Institute of Industrial Engineers, May 21, 1957.

developed a precision boring machine, used in aircraft equipment production, that can bore holes with an accuracy of one-thousandth of an inch. Electronic signals from a tape move the blank metal back or forward, rotate it into position, and then turn on the boring mechanism to cut the hole exactly where it is desired. This automatic machine is specially suited for a medium-sized production, in lots of several hundred parts.

The retailing field has also put automation to use, particularly in inventory control. The special-purpose inventory-control computer at the John Plain Mail Order Company in Chicago is reported to handle 90,000 tallies a day, keeping track of inventory on the 8,000 items in the firm's catalogue.

White collar workers are perhaps feeling the greatest impact of automation. For example, a fairly large insurance company uses a general-purpose computer for 7,000 daily premium billings and accounting, 20,000 monthly dividend calculations and accountings, and 130,000 monthly agency commission calculations and accounts. It is reported that the management of this company feels that it will run the computer an average of 60 hours a week and there will be a saving of from 175 to 225 clerical personnel.

Problems of Automation

It is, of course, easy to realize that all of this automation will have tremendous implications for the national economy.

Automation will increase productivity considerably. But increased manhour output without increased total production and growing consumer markets is a formula for depression. Without customers for the mounting output made possible by rising productivity, unemployment is inevitable.

Unfortunately, there is no automatically self-adjusting market to immediately absorb the yearly increases in the labor force, as well as workers who will be displaced or require retraining. And we lack a self-adjusting economic mechanism to provide immediately a rapidly-rising consumer buying power to sustain high levels of production and employment as the potential output of goods rises rapidly.

This country is not alone in realizing that automation is upon us. There is, however, some question in the minds of many whether or not the government, people in industry, and those who are the leaders in our economic strategy are probing the depths to which automation will affect this country as are governments such as England.

In March of 1956, the Department of Scientific and Industrial Research of Her Majesty's Government in England devoted a very extensive study to automation and all of its ramifications. In summarizing some of their conclusions, the department says, and I quote:

> As experience of automation grows, its future importance to the nation becomes increasingly apparent. Like other advances in technique, it will increase efficiency and should, therefore, reduce costs . . . automation can also increase living standards although it is difficult to forecast how the gains will be divided. On the social side, it seems likely to increase the national requirements for skill and cut out a number of the dull and fatiguing jobs.
>
> At the same time automation is likely to create serious problems, most of them common to all forms of technical advance, and industry must solve them as automation processes are to spread widely without the social and economic dislocaton which marred the early history of the Industrial Revolution.
>
> So far as factory management is concerned, automation increases the need for planning in order to minimize the technical inflexibility of highly integrated plant, to establish preventive maintenance and to provide for continuous running of machinery. Techniques of management that are now needed to handle labor will give ground to new techniques that suit automatic processes, for instance in the systematic study of operations, the use of computers and the control of costs.
>
> Finally, the transition to automation will be greatly extended if attention is given to the needs, feelings and problems of the workers concerned and if the trade unions are consulted in advance of each step. At present, interest tends to be focused on the possibility of automation causing unemployment. But this is not likely to be a serious problem if its introduction is not too rapid and if a state of full employment continues so that re-trained workers can be carefully reabsorbed. It is important, however, that firms should plan their manpower requirement well ahead in terms of numbers, skill and formal qualifications, and so avoid, wherever possible, the risk of having too much or too little labor.

And the report goes on to say, and I believe this is perhaps most significant, and I quote:

> In conclusion, one truth stands out from this report . . . the imperfection of present knowledge and the economic and social aspect of automation, when compared with the knowledge of the technical possibilities. It becomes more vital each year to extend more of these aspects by research and exchange of experience, especially by case histories of firms with automatic processes.

In quoting so extensively from the British Government's Report, I do not mean to minimize the awareness which is at least evident on the part of some of our leading governmental officials. In a statement from the subcommittee on economic stabilization, we can see that they too realize the significance of the economic and social aspects of automation. In their report they say:

> However much we may recommend the advancing technology —however optimistic we may be that the problems of automation will not be serious—no one dares overlook or deny the fact that many individuals will suffer personal, mental, and physical hardships if the adjustments go forward.
>
> The best, and by far the most important single recommendation which the subcommittee can give is that the private and public sections of the nation do everything possible to assure the maintenance of a good, healthy, dynamic and prosperous economy, so that those who lose out at one place as a consequence of progressive technology will have no difficulty in finding a demand for their services elsewhere in the economy. . . .
>
> The subcommittee recommends that industry, and management for its part, must be prepared to accept the human cost of displacement and retraining as charges against the savings from the introduction of automation.

My purpose in quoting from these sources is to lay the foundation for the position that labor has taken in regard to automation. In every sense, I believe that labor looks on automation as a means to an end and intends that automa-

tion should be made the servant of man and not the master.

Perhaps at this point I should mention a little story in connection with the Ford Motor Plant at Cleveland which we discussed earlier. The story is told that Walter Reuther, while being shown through the plant by one of the Ford executives was kidded a little and told, "You will never be able to collect union dues from these machines," and he replied, ". . . . they will never be able to buy Ford automobiles either." Along this line, the New Yorker magazine recently carried a cartoon of a business executive taking his wife out for a ride on Sunday and they decided to go by the plant which he owned. Suddenly he exclaimed to his wife, as they looked at the plant with materials oozing out of the doors and windows—"Oh, my God, I forgot to turn the plant off for the weekend!"

So I say, labor would like to first of all point out the problems—problems that are of a national scope. These are things that all of us can and should be concerned about:

Will consumer purchasing power rise sufficiently to provide the rapidly growing consumer markets needed to match the increasingly automated productive capacity of industry and commerce?

Will economic activity expand fast enough during the transition period to provide job opportunities for new workers entering the labor market, as well as for workers who are displaced by automated machines and electronic computers?

Will the costs of introducing automation be so great—and the required output so large—as to produce an increased tendency toward concentration of the control of industry?

Will automation speed up the increasing productivity of capital investment (output per unit of capital)? Will private consumption and government expenditures, in combination, grow sufficiently to maintain expanding markets, if the productivity of plant and equipment rises rapidly?

Will automation result in the creation of much secondary investment and new jobs, as did the introduction of the automobile and the ensuing developments in road construction, steel, oil, rubber, and glass?

How will automation affect plant location? Will firms prefer to build automated plants in new areas, rather than to renovate existing plants? Will automation encourage abandonment of existing facilities, loss of industry, and economic distress for many communities?

Are the schools training a sufficiently large and adequately skilled labor force to operate and maintain an economy that will be increasingly automated? Is the school system prepared to meet this responsibility?

Will the nation's educational, cultural and recreational facilities be capable of meeting the challenge of increased leisure made possible by automation—longer vacations, reduced work-weeks, two-and-a-half or three-day weekends?

But, of course, our main concern is with the impact of automation on workers. Automation promises the elimination of routine and competitive jobs. It makes possible the creation of greatly improved working conditions and the reduction in length of the work-week.

Collective Bargaining

But even in periods of high employment we know that the introduction of automation means some workers will suffer layoffs. Academic assurances that 'all will work out in the long run' is of no help to the displaced worker and his family who are directly affected. This presents a challenge to the collective bargaining processes and is the mutual concern of labor and management to assure that all the benefits the American worker has achieved over many years will continue.

We feel that the processes of collective bargaining can and must be used to plan carefully for the introduction of automation to minimize the job and hours lost to the employees.

Organized labor is also alert to the need for workers to adequately share in the fruits of rising productivity, substantial wage increases and—barring increases in international tensions—a reduced work-week and thereby be able to spread the benefits of automation to the greater mass of American families.

Along this line, I would like to note here that this abundance of leisure time will in itself present an increasingly important problem which will have to be met, especially in the field of human engineering. I think that it would be of great interest to your group, as well as to others, to discuss the effect of increased periods of leisure time on the social structure of our society.

Methods of Solving Problems

But to get back to how labor looks at automation, the following statements are generally the feeling of labor as to methods in solving the problems:

A financial cushion for workers where layoffs do take place, and a financial incentive for management to plan ahead to minimize employee dislocation, can be provided through labor-management agreements on guaranteed wage plans and severance pay provision.

Collective bargaining can also provide other necessary safeguards. These include the need for fair and orderly procedures governing lay-offs, rehires, transfers, promotions, and changes of job classifications and wage structures. There are a multitude of important details to be worked out in labor-management negotiations.

It may be necessary, for example, substantially to revise seniority provisions in collective bargaining contracts. Unions are giving much thought to the need for the broadening of seniority areas—company-wide or plant-wide seniority, for example—to assure equitable seniority protection for their members and the right to inter-department and inter-plant transfers, based on seniority. Preferential hiring provisions are being considered, which would require all plants under contract with the union to give preference to laid-off workers in the same industry and area.

Also, seniority systems should assure senior employees a full opportunity to qualify for new higher-skill jobs. Such employees should not be passed over in favor of new or junior employees simply because of age or an employer's unwillingness to provide the training to enable qualification for the job.

Significant changes will be required in wage structure. New job classifications and new wage structures will have to be worked out, as job content changes. With the upgrading of skills and rapidly rising productivity, wage

rates will have to be revised upwards after automation is introduced into a firm. Existing job evaluation plans will have to be thoroughly revised or discarded; wage incentive systems may have to be eliminated.

Problems of down-grading will probably develop, as the need for certain types of skills are made obsolete by new automatic machinery, or as some workers, unable to adjust to changed jobs, are shifted to lower-rated jobs. Special job-and-wage protections will have to be worked out for them.

Pension plans may also have to be changed through the collective bargaining process, particularly to permit earlier retirement and the transfer of pension rights from one plant to another within an industry or area, so that displaced workers are not hit by loss of accrued pension rights.

Many unions will probably demand contract provisions for the re-training of workers at company expense. Some unions have already initiated training and re-training programs to familiarize members with new mechanical and electronic processes.

Mr. Beirnie, president of the Communication Workers, reports that they are specifically asking the Bell System and other major employers to provide cooperation on the following points:

1. A shorter work-day and a shorter work-week for all workers.
2. Improved force reduction and hiring procedures.
3. Interdepartmental and intercompany transfers including payment of transfer expenses.
4. Higher pensions and lower optional retirement age.
5. More liberal termination payments for those who lose their jobs as a result of technological changes.
6. Better and more extensive job retraining programs.
7. Longer vacations.
8. Improved seniority arrangements.

Mr. Beirnie reports that union-management cooperation in these areas as a rational management approach to wages and hours, would work wonders in minimizing the hardships that automation has, and will most certainly bring. He goes on to say, ". . . we have had only resistance from the Bell system management, which seeks to substitute a father image for collective bargaining in its relations with its workers." What is true of the Bell System is also true in far too many other of our major corporations.

Another large international union says that the union must insist on contract provisions that will provide these following points:

1. A joint union-management committee to study problems arising from automation.
2. New and higher job classifications and rates for workers on automatic equipment.
3. Production bonuses.
4. Revision of seniority and transfer provisions including preferential hiring, to give displaced workers a better chance to get other jobs.
5. A guaranteed annual wage and dismissal pay.
6. Provision for training and retraining at company expense of automation workers within the plant.
7. Broader seniority protection.

As I mentioned in my introduction, I am not an expert on automation, and labor does not feel that it has all the answers to the problems which will arise as a result of this advance technology. Problems which are coming up everyday are being negotiated out on a local plant-by-plant basis. Local plant management and local union officials are doing what they can, but they need guidance and assistance especially in working out the human problems which are involved. Whatever the attitude of management, however, it is the dedicated purpose of our movement to make automation the new servant of the people, not their master.

The developing issues in the many ramifications of automation require earnest consideration by all segments of our society. Unions are now studying closely the effects of automation in their respective industry. Union staffs and technical consultants are working with negotiators to develop means of easing any adverse effect of the new advancements.

In cooperation with managements and the government, unions hope and expect to develop realistic solutions to the difficulties that may arise. The problems posed by automation can and must be worked out by the joint efforts of labor, management, government and other groups in society, if the transition to the new era of the new technology, and the achievement of its potential for vast improvement in our standards of living, is to be accomplished with a minimum of social dislocation and human suffering.

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A Mathematical Model for Job Evaluation

By T. E. Bartlett

Assistant Professor, Department of Industrial Engineering, Purdue University,

F. R. Cassilly

Lieutenant, USN

and H. W. Jones

Lieutenant, USN

The past few years have seen the introduction of new techniques and concepts which are proving increasingly useful in the field of Industrial Engineering. Among the most promising of these has been the tool of the physicists and others—the "mathematical model." Like any other good tool it is subject to misuse. On the other hand, it appears to offer a great deal in the analysis of the extremely complex systems with which the Industrial Engineer is constantly working.

While there exists a modest number of examples in the literature of the application of this tool to the field, it is safe to say that more has been published about the potential applications than about results. The most obvious and frequently referred to use for the mathematical model lies in its ability to handle many complex problems which we did not understand except at a very superficial level. Another use which is not so well publicized, but which may prove even more important, lies in its ability at times to evaluate existing procedures with which we are presently "solving" problems.

One of the areas of interest to the Industrial Engineer for which "problem solving" techniques already exist is that of Job Evaluation. In this area a popular misconception exists that the present techniques qualify as mathematical models because they utilize at times a fairly elaborate series of arithmetic steps. Suffice it to say that quantified values and a partially structured logic do not necessarily create a mathematical model. The state of development in Job Evaluation leaves much to be desired in terms of a mathematical model. Those parts of it which are "quantified" and rigorously structured are hung together by not too well defined narrative logic and, in some cases, mathematical non-sequiturs.

The development which follows is the result of a joint effort on the part of the authors to investigate the field of Job Evaluation in the light of more rigorous mathematical analysis. It is not intended here to suggest improvements to, or expanded applications for, any job evaluation system. It is felt, rather, that a fresh approach to this subject is needed, and that the statement of the underlying mechanisms in mathematical terms will provide such a fresh approach. At the conclusion of the article a number of questions are raised which appear to imply criticism of Job Evaluation. The only reason for including these points is that they appear to provide a basis for future development and refinement in an important area of Industrial Engineering.

Background of Job Evaluation

Job evaluation is, in general, a set of methods for determining the wages to be paid for the performance of a collection of tasks under a specified range of conditions. In many large organizations and in the goverment it is implemented by a staff of one or more people—frequently in the Industrial Engineering Department or its equivalent—who specialize in the administration of the wage structure. The bulk of the activities assigned to these people is made up of the determination and redetermination of wage or salary rates for jobs. The task of assigning rates to particular jobs begins with the collection of information about the job under consideration, other jobs in the structure and, sometimes, jobs outside the structure. After the data are obtained, a "formula" or set of formulas is applied to obtain the rate.

The particular method which is used in an organization is usually tailored to fit the situation at hand, but for purposes of discussion in the field they are somewhat standardized. These various methods are usually divided, therefore, into four categories: Job Ranking, Job Classification, Factor Comparison, and the Point Method. The first two of these have been tagged "non-quantitative" and the latter two "quantitative," although such labelling has little precise meaning.

Various claims are made regarding the objectives of job evaluation. Authors in the field state the claims in

different terms, but the following statements comprehend substantially all of these claims:

1. It is systematic, routine, and subject to centralization, thereby reducing or eliminating the time spent by the foreman or supervisor on the determination of individual wages.
2. It is more easily controlled and administered than are the available alternatives, thereby eliminating the growth of inequities due only to administration of a wage system.
3. It provides a less subjective method for comparison of nonrelated jobs so that wages may be paid related to some aggregate quality of "job difficulty." Most authors and practitioners in the field tend to carry this to its extreme and claim that a particular system is independently valid.

There are certain additional advantages claimed for job evaluation, but they are in a sense second-order. It is, for example, contended that job evaluation will "reduce grievances and turnover."[1] In order that grievances and turnover be reduced by job evaluation, however, it is necessary to assume that they are related to wage inequities developed through the structure or administration of the wage program. Whether or not they are directly related has not been too well developed. (Recent studies tend to place wages well down the list of the reasons for turnover.) In any event, this advantage and others are comprehended by the three basic statements above.

The theory and method of existing job evaluation systems are subject to a certain amount of valid criticism. While it is well accepted that some method must be used in determining wages, and further that the present methods present a systematic attack on the problem, there exists reasonable doubt as to the validity of all of the claims made for them. It is also true that there exists the possibility of improving the present methods or finding a superior method.

The General Banking Principle

All wage administrators recognize, at least implicitly, that this "less subjective" evaluation must be consonant with the realities of wages being paid and the necessity of economical operation; their superiors primarily want order and control, rather than conformance with more nebulous sociological or economic goals. We hope to show here that all four common evaluation plans are specialized forms of a general direct answer to this demand.

Let us proceed to hypothesize this direct answer. It is always assumed that pay rate will vary with the individual jobs, although some jobs with quite different content may properly be paid the same amount. It is further assumed that an orderly system will associate the different wage rates paid with some set of variables which are subject to reasonable estimates of measurement, either directly or indirectly. Thus in practice we obtain a first order calculation to be performed, namely: a ranking of jobs.

In the preliminary stages, the evaluators are first asked to rank all jobs in order, according to the relative worth. In order to fix a value, a rating, R', corresponding to rank in some arbitrary continuum, is associated with each job, where

$$R'_j \equiv f(t; X_{1_j}, X_{2_j}, \cdots, X_{n_j}) \qquad \text{Eq. 1.}$$

in which t is time, X_{i_j} is the amount of the ith of n factors of "worth" or commonly "job difficulty", contained in the jth job and R'_j is the aggregate "worth" of the jth job. Time is included as a dependent variable in recognition that different results would be obtained at different times.

Pay rate P is assumed to be a function of R', say

$$P = g(R') \qquad \text{Eq. 2.}$$

For some arbitrarily selected set of "key" jobs, $P = g(R')$ is plotted against R'. It is through assuming appropriate pay scales for these key jobs that the wage administrator makes his contact with reality. The resulting function must be monotonically increasing with higher rank, since in no system can the higher ranked job be allowed to receive lower pay. The evaluation system is thus required only to *rank* the key jobs correctly and not to determine the degree of difference in rank. This difference only becomes important should the evaluator try to impose some particular form on the function $g(R')$.

It is obvious that the selection of key jobs in any *a priori* manner will probably result in a $g(R')$ of irregular shape. This is a direct result of assuming rank only is of importance, and the curve $g(R')$ will be of varying slope accordingly as the difference in actual value of R' between adjacent ranks is not constant.

Now consider the matter of time appearing in the function R'. It is an essential assumption in any job evaluation system that the ratings of aggregate worth remain constant over a useful period of time, i.e. that

$$\frac{\partial R'}{\partial t} = 0 \qquad \text{Eq. 3.}$$

remain essentially true in the period between re-evaluations. Thus for the purposes of evaluation, the rating R' can be equated to a rating R so that

$$R'_j = R_j \equiv f(X_{1_j}, X_{2_j}, \cdots, X_{i_j}, \cdots, X_{n_j}) \qquad \text{Eq. 4.}$$

Now also

$$P = g(R) \qquad \text{Eq. 5.}$$

Note that this last statement does not imply constant proportionality of worth to compensation. This fact is of importance in considering the effects of general changes in pay scales. Such changes represent a transformation on the function $P = g(R)$. Symbolizing this transform by p, then

$$P' = p(P) = p[g(R)] \qquad \text{Eq. 6.}$$

Pay changes of either the flat cents or per cent of pay rate type can be made without being inconsistent with the evaluation in use. It is only when the transform, p, is

[1] Lanham, E. *Job Evaluation*, McGraw-Hill, New York, 1955.

not monotonic that a re-evaluation is essential, for then the possibility of rank-pay rate inversion is introduced.

It is necessary, however, to interpolate on the plot of $P = g(R)$ for the other jobs. This task does require that some evaluation be made of the actual difference in worth between ranks. It is worth noting that the plot of pay versus rank can be linearized by performing the monotonic transformation $g(R)$ upon the coordinate R. This may be done in practice by graphic means if desired in the usual case where $g(R)$ does not take on a shape for which the mathematical expression is apparent.

The Job-Ranking System

In the Job Ranking System, the evaluation group is asked to rank all jobs without regard to degree of difference by mentally evaluating the function

$$R_j = f(X_{1_j}, X_{2_j}, \cdots, X_{i_j}, \cdots, X_{n_j}) \quad \text{Eq. 4.}$$

The ranks determined are compared with present pay rates. Any minor inconsistencies are resolved by adjusting the pay since it is agreed beforehand that

$$a_j \leq P_j \leq b_j \quad \text{Eq. 7.}$$

where a_j and b_j are constant limits and P_j is the pay rate of jth job as finally determined. This only says that acceptable pay for jobs is not definite, but covers a range. But note that this can only correct inconsistencies of a limited nature. If the evaluation produced inconsistencies which could not be resolved, the group would be forced to start again with a new or modified description of the functions Eq. 4. and Eq. 7. In actuality they are merely being called upon to reproduce the acceptable wage pattern by a set of values, $(X_1, X_2, \cdots, X_i, \cdots, X_n)$ described by management as determining job worth. If this proves to be impossible, the raters must recognize the inconsistencies and choose from among the following alternatives:

1. Make an arbitrary reassignment for the sake of consistency only.
2. Re-evaluate the rankings, admitting the possibility of additional factors of worth—a change in Eq. 4.
3. Utilize a new range of values, a_j and b_j.

The Job Classification System

In the Job Classification System an arbitrary ranked series of classes is established. For each class the content of typical jobs which fall therein is described. Sufficient classes are chosen so that every job may be placed in one of them. Again, the pay for jobs in the jth job class is acceptable if

$$a_j \leq P_j \leq b_j \quad \text{Eq. 7.}$$

The constants a_j and b_j are determined by the degree of overlapping of pay range between classes deemed permissible. All jobs are assigned to appropriate classes—a procedure which corresponds to ranking the jobs among a limited number of rank positions. Actual wages are then compared with the wages assigned for the class to which they have been assigned. If the limits in Eq. 7. cannot be met without undue tampering with present wage scales, then for the system to be useful the set of classes must be revised, usually by decreasing their number, increasing the permissible range, or revising the descriptions.

The design of a specific job classification system requires, then, the construction of a stepped series of job descriptions which will allow any skilled rater to select from among the series a set of ranks corresponding to particular jobs which will plot $g(R)$ as monotonically increasing. As in the job ranking system, minor inconsistencies can be resolved under the permissible slack

$$a_j \leq P_j \leq b_j \quad \text{Eq. 7}$$

Factor Comparison Method

In the Factor Comparison Method special assumptions are made about the function R defined by Eq. 4. Key jobs are assumed to be paid correctly according to some predetermined pay scale. The evaluators then rank the key jobs in n series, according to the amount to which each of the n factors of worth enters into each job. Thus to each job is attached n ratings,

$$R_{i_j} = X_{i_j} \quad \text{Eq. 8.}$$

where R_{i_j} is the rating of the jth job on the ith series and X_{i_j} is the amount of the ith factor entering into the jth job. A suitable pay scale for each of the n ranking series must be established, and one that is monotonically increasing with R. The suitability restriction is that

$$P_j = \sum_{i=1}^{n} P_{i_j} = \sum_{i=1}^{n} g_i(R_{i_j}) = \sum_{i=1}^{n} g_i(X'_{i_j}) \quad \text{Eq. 9.}$$

where P_j is the assumed correct pay rate for the jth job, P_{i_j} is the pay rate established for the amount of the ith

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factor in the jth job, and the function g varies with the independent pay scale of the ith factor. The solution for these n pay scales is a problem of some difficulty. The usual method of approach is as follows. First distribute the given pay rate among the n factors according to any reasonable estimates for all the key jobs. After distributing the pay, compare those partial rates with the rankings as determined by Eq. 8. An attempt is made to adjust this preliminary distribution to eliminate inconsistencies with the ranking. Any jobs not permitting such adjustment are cast out of the scheme as not "key" jobs. These n pay scales are then used to determine the pay rates for all jobs by a process of interpolation. To the extent that jobs were removed from the key job list or other jobs are compared with the scales with unhappy results, the system is in conflict with management desires.

There is a certain rigidity imposed on this system, not present in the other three. This is evident from the lack of any range in permissible pay rates, or "slack" allowance. If it is permitted to the evaluators to recognize that there may be k additional "slack" factors in job worth the equation in this system may be expressed in a form suitable for a solution by a linear programming minimizing technique. Then

$$\sum_{i=1}^{n+k} P_{i_j} \geq P_j \qquad \text{Eq. 10.}$$

in which the sum of the partial pay rates of the jth job is greater than the total actual pay by the amount of the additional factors. Then a criterion for best solution might be the minimizing of the pay for additional factors, or

$$\min \sum_{i=n+1}^{n+k} \sum_{j=1}^{m} P_{i_j} \qquad \text{Eq. 11.}$$

in which $\sum_{i=n+1}^{n+k} P_{i_j}$ is the additional pay for the jth job. This is one method by which slack could be introduced. A little reflection should suggest others.[2]

The Point System

In industry today the Point System is the most widely used, and it is therefore interesting to note that it can be developed most naturally from the hypothesized model.

This system gives definite form to the rating function R. "Points" are the unit of measure in R, defined by

$$R = \sum_{i=1}^{n} a_i(X_{i_j}) \qquad \text{Eq. 12.}$$

where X_{i_j} is, as before, the amount of the ith factor in the jth job, and a_i is a weighting factor for the ith component of job worth. The usual slack is allowed by management in the adjustments to present pay scales in order to construct a monotonic function $P = g(R)$, expressed in Eq. 7. It is the task of the evaluation program to adjust the weighting factors and the number and character of the factors to allow construction of $P = g(R)$, that is both consonant with management desires and also monotonic. As in the Factor Comparison method the form lends itself readily to linear programming.

The General Model

It is possible now to reiterate and state the basic functions of job evaluation in mathematical terms.

1. Raters are required to rank jobs according to a measure of worth R, a function of the factors of "job difficulty." This is expressed as

$$R_j = f(X_{1j}, X_{2j}, \cdots, X_{ij}, \cdots X_{nj}) \qquad \text{Eq. 4.}$$

2. The assumed correct pay P_j is plotted for all j against rank to form

$$P = g(R) \qquad \text{Eq. 5.}$$

which must increase monotonically with higher rank for the system to claim validity.

3. Minor adjustments can usually be made under slack condition allowed the wage rates in

$$a_j \leq P_j \leq b_j[3] \qquad \text{Eq. 7.}$$

In regard to the matter of actually drawing in the function $g(R)$, it might be worth pointing out that least squares techniques are applicable to construction of parabolic, exponential, or polynomial, as well as linear relationships. Any type of likely looking monotonic curve may be so plotted and standard statistical tests applied to determine if chance causes of variation can explain the deviations then observed.

Conclusions

It is strongly suggested by the foregoing analysis that the results of job evaluation may not possess the force of

[2] In "Optimal Estimate of Executive Compensation" by A. Charnes, W. Cooper, and R. Ferguson, *Management Science*, Vol. I, No. 2, January, 1955, the authors have utilized a clever device of maintaining rank while permitting some of the Pay Raters to vary by minimizing the sum of the absolute differences from the present pay rates. In the notation of the present discussion, this formulation is

$$\min \sum_{j=1}^{m} \left| P_j - \sum_{i=1}^{n} P_{i_j} \right|$$

$$\text{S.T.} \sum_{i} P_{i_j} \leq \sum_{i} P_{i_{j+1}}$$

and additional appropriate constraints.

[3] An alternative or additional constraint may be imposed by management as either

$$\Sigma P_j - P_j' \leq K$$

or

$$\Sigma b_j(P_j - P_j') \leq K$$

in which b_j represents the number of hours presently worked or to be worked on job j for a given period, and P_j' represents the present rate of pay. The effect of this constraint is to place a bound on the total increase in pay permitted by a job evaluation program. Other common policy restrictions by management may be handled by appropriate choice of functional or constraints in a programming model.

independent validity which most authors claim for it. Company wage policies and decisions cannot logically emanate from such a system, for it appears that all four systems are merely control procedures for policies established on a higher level. Most job evaluation systems are administratively complicated, and it is only too easy for such instruments gradually to gain over management decisions an influence which is not justified by the system's logical framework.

Since this dependence on management policy for validity is a characteristic of current Job Evaluation techniques, a reassessment of management's role in the determination of the wage structure may be in order. It is possible that a new set of questions should be raised at the policy-making level. For example: which system should be adopted by a particular company? If, as indicated, all systems are lacking in ability to construct a wage structure except as directed by competent authority, the immediate implication is that such questions should be answered on a practical basis. On the specific question above, a management might wish to scrutinize the alternatives on the basis of ease of computation, acceptability to employees, or degree of sophistication. Such practical considerations may well outweigh the usual quasi-theoretical considerations concerning the shape of the wage structure, the ability of a system to handle rater bias, and others.

If job evaluation serves only to organize and control, then how broad is its useful field of application? Of what size or complexity should a company be for these advantages to outweigh the cost and rigidity of such a program? Is it really applicable in the shifting sands of executive compensation?

It is hoped that these and other questions may receive quite different answers when job evaluation is reconsidered as one more problem which is subject to logical analysis rather than in the usual context wherein the discussion is clouded by too close consideration of details of technique.

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Some Developments in the Relationship between Collective Bargaining and Industrial Engineering[1]

By William Gomberg

Professor, Industrial Engineering, Washington University

The problem of the setting of production standards in collective bargaining is rapidly coming to the forefront again. Competition among the big three auto manufacturers has led to a review of production costs. Attempts to revise production standards led to a five week strike at the California plant of the Chrysler Corporation. The bitterness of the dispute flowed onto the convention floor at Atlantic City where the United Auto Workers were assembled in their biennial convention. It becomes timely once again to review the status of Industrial Engineering vis-a-vis collective bargaining.

The special Industrial Engineering techniques of interest to the trade unionist cover the whole gamut of management. Items remote from the employer-employee relationships like sales management, production scheduling and routing have their impact on the employer-employee relationship. They determine the effectiveness of the business, the profitability of the enterprise and the ability of the employer to pay the workers not only a living, but a prosperous wage. However, the techniques that remain of most immediate interest to the trade unionist are largely confined to those that arise in the day-to-day collective bargaining relationship. The immediate disputes in which both engineer and shop steward find themselves engaged cover the area of job evaluation, production rate setting by time study, and the administration of wage incentive payment plans. These techniques were found particularly useful by the trade unionist during World War II.

The evolving relationship between the Industrial Engineers and the trade unionists during this period, can best be understood against the background of the special problems that the labor movement faced during the war.

The labor movement had not had an opportunity to really digest its newly found members immediately prior to World War II. The great organizing campaigns that began with the sit downs in rubber and automobile in 1937 had brought thousands upon thousands of workers into the trade union fold. The normal maturing process during the course of which local leadership would be trained to handle the day-to-day tasks of the shop stewards and shop committees has not had an opportunity to operate.

Management, for its part, had not yet really reconciled itself to the permanent establishment of a trade union movement, as a normative part of our industrial culture. A newly organized Liberty League, made up of management's leading legal luminaries, had gratuitously usurped the function of the Supreme Court of the United States and declared the Wagner Labor Act unconstitutional in the mid-1930's. The result was that between the passage of the Act and the declaration of its constitutionality in 1937, management had felt free to behave towards unions in very much the same pattern that they had pursued in the 1920's; or at least, if they had to compromise, felt that this was but a temporary stratagem, pending a final showdown when a return to the country's political climate of 1920 would make such an undertaking feasible.

The declaration by the Supreme Court that the Wagner Act was constitutional came upon management like a thunderclap in the middle of the night. It was not prepared to meet this obligation emotionally or operationally. Management's churlish self-righteousness had elicited a corresponding antagonistic attitude from the trade unionist and each side had squared off in its corner. An uneasy truce only kept them from coming to blows. The constitutional verification of the Labor Act started a normal maturing process that did not receive much publicity. This maturing process was frustrated when the United States found itself embroiled in the second World War.

Labor was called upon for a no-strike pledge and in return the government, through its various commissions like the War Labor Board, provided what amounted to tribunals that imposed compulsory arbitration of disputes on both sides.

The inflationary pressures that began to build up under the stress of the industrial war effort led the government to impose a ceiling on wage increases. The labor movement felt completely thwarted. They reasoned, "It's obvious that it is difficult to strike successfully when there are nine million unemployed such as there were in 1939 in order to get any decent wage increase. And now the

[1] Prepared with the assistance of The Social Science Institute.

government tells you that you can't strike when there is a labor shortage."

Strategically, we are always in the position of "heads they win and tails we lose." This was the prevailing temper.

Job Evaluation

It was the job of the War Labor Board to administer the anti-inflation program through the government in such a way that wage adjustments could be carried on without increasing the labor costs of the products being manufactured. Suddenly the engineers and the trade unionists found themselves in an uneasy alliance. One of the rules promulgated by the War Labor Board was that a restricted amount of money could be added to the payroll to correct inequities in the wage structure. The trade unionist turned to the job evaluation specialist to make the inequities look big. Management turned to the job evaluation specialist to make the inequities look small.

Wage Incentives

The War Labor Board, caught in between, developed its own formal job evaluation procedures in order to rationalize its decisions between the contending experts. Wage incentive payment plans and the required procedures for setting production standards underpinning the plans were suddenly adopted by unions who had long opposed any wage payments by results. In many cases these wage incentive payment plans led to increases in production for which workers were correspondingly rewarded.

In other cases, there were favorite devices for the avoidance of the War Labor Board restrictive regulations. It was a relatively easy matter to enforce regulations governing straight time payments to workers. All that was needed was inspection of the payroll books. The administration, however, of complicated piece rates was completely beyond the capacity of the War Labor Board. The dynamic behavior of American industry meant that old methods of making old products rapidly became obsolete. New methods were being devised for making new products; new ways were being developed for making old products; and finally, new methods were perfected for making new products. This lent American industry its élan. However, it meant that the administrative job of the War Labor Board was hopeless. Who was competent to check whether or not every production standard and every time study was set to yield the legal earning opportunity specified by the little steel formula?

The engineers took their consulting fees, the employers took their prices, the workers took their wages, and old feuds were buried and the basis for new conflicts was laid. Statement after statement, directive after directive, memorandum after memorandum were issued from the War Labor Board in a futile attempt to cover with rhetoric what could not be handled operationally. Everybody was happy except the long term economist. Everybody was busy living in the short run. Then the war ended.

The employers were frightened by their complete confusion and their inability to see the new market. Many of them compensated for their fears by wild talk about how they were going to teach labor its place.

The labor movement was frightened. It remembered that in 1919 and 1920 the great organizational gains of World War I had been completely liquidated by a post-war union busting campaign.

The N.A.M. had promulgated the American Plan, and within a short time organized labor ranks had been decimated. Woodrow Wilson had convened an industrial relations conference in 1919. It was made up of the leading members of the labor movement and the leading management members of the country. The tone of the conference was set by Elbert H. Garry, President of U. S. Steel. The conference recognized the right of every worker to join a union, and the right of every employer to either deal with a union or not, as he chose. Most of management chose not to deal with a union. To be sure, there were isolated islands of union-mangement cooperation experiments here and there, like the Baltimore and Ohio plan. But, by and large, the policy of American management that counted was to fight actively the trade union movement. The question in the minds of the trade unionists at the end of World War II was, "Will history repeat itself?"

Labor and Management

On the other hand, the engineers provided a breach in the mid-1920's in the solid front of management thinking. The scientific management movement voiced a refreshing departure from the prejudices of top American management. The Industrial Engineers, under the leadership of men like Harlow Persons and Morris L. Cooke, had worked successfully with the trade unionists during the war. Immediately after the war, they were prominently identified with outstanding union-management experiments like the joint application of time study to setting incentive wage rate standards in the Cleveland ladies' garment market. This experiment was conducted under the leadership of Morris L. Cooke, an old associate of Frederick Taylor who had become a close friend of Samuel Gompers during World War I.

The Taylor Society provided a forum for the dissident thinkers among management, including men like Otto Beyer who was responsible for the administration of the B. & O. Plan. They reprinted in their Journal the classic paper of R. G. Valentine, "The Relationship Between Efficiency and Consent." This was the first paper to lay down a philosophy upon which both management and labor could cooperate within a scientific management frame of reference.

This was the historical experience which labor, management, and the engineers brought to 1946. The engineers had their dissident left wing tradition upon which to draw. The employers had their fighting slogans to which they

could return, and the insecure labor movement had its bitter memories with which to project the future.

President Truman, like his predecessor, Woodrow Wilson, also called a labor-management conference. A key subcommittee of the conference, made up of an equal number of representatives from management and labor, was the Management's Right to Manage Committee. The committee was unable to agree.

The management members addressed a letter to the conference, extracts from which follow:

> Labor members of the committee on Management's Right to Manage have been unwilling to agree on any listing of specific management functions. . . . If labor disputes are to be minimized by the genuine acceptance by organized labor of the functions and responsibilities of management to direct the operation of an enterprise, labor must agree that certain specific functions and responsibilities of management are not subject to collective bargaining.

The committee then went on to list some of the duties which they felt were outside the jurisdiction of collective bargaining:

> The location of the business, including the establishment of new units and the relocation or closing of old units. . . .
>
> . . . the determination of job content; the determination of the size of the work force; the allocation and assignment of work to workers.

The labor group, on the other hand, pointed out that:

> The extensive exploratory discussions of the committee have brought forth the wide variety of traditions, customs and practices that have grown out of relationships between unions and management in various industries over a long period of time.
>
> It would be extremely unwise to build a fence around the rights and responsibilities of management on the one hand and unions on the other. The experience of many years shows that with the growth of mutual understanding the responsibilities of one of the parties today may well become the joint responsibility of both parties tomorrow.

Labor was, in short, accusing management of committing the logical fallacy of "false concreteness," a favorite fallacy of the legal-minded who must fit all living phenomena into a system of verbal categories. It was in this environment that the labor movement philosophy of Industrial Engineering developed.

In the midst of this labor-management conference in December, 1945, the United Auto Workers, under the leadership of then Vice-President Walter Reuther, called a strike against General Motors Corporation that was to last 118 days. Reuther demanded that the corporation increase wages 30 per cent and offered to prove, if management would open its books, that the corporation could afford to pay this increase, reduce the price of a Chevrolet $50, and still make the largest profits in its history.

The anger of the company was more directed at the Reuther proposal that they open their books and the invasion of the area of price policy than at any of the economic demands. They accused him of using the union to promote a socialist ideology, and insisted that price policy and ability to pay were outside the scope of collective bargaining.

Among the counter demands served by General Motors Corporation upon the union was the extension of the work week to 45 hours per week at straight time, and *the institution of wage incentive payment plans* all over the General Motors empire. The attitudes within the U.A.W. on wage incentive payment plans during the war had been a matter of dispute. One faction called for their promotion in order to cope with the ceiling imposed by the little steel formula. The other group, remembering the bitter experience of the automobile workers during the '30's when piece rates were cut unilaterally, wanted no part of these plans. The demand of the corporation that the plans be spread solidified the entire union behind the position of opposition to the plans.

The official policy of the United Automobile Workers remains opposed to wage incentive payment plans. However, it was with great reluctance that the auto workers were forced to abandon a wage incentive payment plan both with the Willys Corporation in Toledo and the Studebaker Corporation. The agreement of December 1, 1954, between the U.A.W. Local #5 and the Studebaker Corporation has appended to it a letter dated August 13, 1954, signed by Paul M. Clark, Studebaker Vice-President, abolishing piece work in the Studebaker plant. Along with it went a reduction in earnings opportunity without a corresponding reduction in work pace. The U.A.W. had undertaken a cooperative effort with the Studebaker Corporation to save the financial position of the institution.

Here it was the union that wanted the continuation of the piece work plan and the company that was advocating its abolition. Here again is proof that the policy of a union towards any of these techniques is dictated by the pragmatic economic requirements it finds on the job, rather than any preconceived ideological position it may take at a convention.

Production Standards

The recent dispute between the Westinghouse Corporation and the International Union of Electrical Workers revolved around the setting up of production standards for indirect maintenance workers. A position paper of the Union dated November 25, 1955, spells out the Union's position. The IUE-CIO has maintained that no work standards should be imposed by Westinghouse on its employees unless the job is put on incentive. The Union maintains that to impose work standards without incentives is to create a "third class" citizenship among Westinghouse workers. Dayworkers on standards would have all the disadvantages of dayworkers (in that they would get no incentive pay), and all the disadvantages of incentive workers (in that they would have to work against a standard).

The Company would have a "one-way street" on this. It claims it can discipline or discharge people who do not meet the standard, but would provide no extra pay for those who exceed it. We maintain that this is not only an unfair and unworkable program, but, in fact, it is contrary

to the generally accepted best practices in American industry.

The interest labor has in rate-setting technique as a collective bargaining tool was clearly established in the arbitration decision following the Ford Motor strike in 1949 over an alleged speedup. The company was told clearly that, although the agreement reserved the right to set production standards, this right was not the same as other management rights. It was not an absolute right. It was a right to initiate as against an absolute right to determine. The final determination that rate setting was a subject for collective bargaining was important in the conflict that was developing between the labor movement and the organized engineers as represented through the Society for the Advancement of Management.

Obviously, if labor had a right to participate in the process of rate setting, it was not going to countenance the imposition of a system of rate setting unsupported by any scientific foundation. What is worse, this code was unilaterally determined by a management society without any labor consultation.

The Society for the Advancement of Management undertook the publication of a unilateral study of the rating process. They published widely the results of a national concensus of management engineers's opinions about what they considered a fair working pace.[2] The reaction of the labor movement was vigorous. After an exhaustive analysis of the study by staff technicians, the labor movement joined in a denunciation of the study. As a result, *The American Federationist* carried a special editorial denouncing the imposition upon workers of such a unilateral study. Walter Reuther, President of the CIO, in a special memo to his officers denounced the study and warned union officers against accepting any of these bench marks as arbitration guides in disputes over production standards.

Recently an attempt was made by an employer to make the S.A.M. rating films the arbitration criterion between the employers and the Carpenters Union in any production standards dispute which may arise. The Union again refused to go along.

Standard Data Systems

The labor movement's attitude towards the microscopic standard data systems that have become fashionable since the end of World War II has been to observe that if one of these systems is right, all the others have to be wrong. And yet, strangely enough, they all work. They work because they create an atmosphere that leads to the working out of what the logicians would call a self-demonstrating hypothesis. The worker knows what the engineer expects. He prefers to avoid fights. He tailors his working pace to suit the expected increment earning. The worker is reasonably happy, the engineer delighted, and the employer is pleased!

By and large, labor spokesmen will do nothing to expel a system from a plant provided it is clearly understood that the system is not the criterion against which the adequacy of any single rate will be measured. They will insist that an arbitrator hearing a rate dispute between the union and any advocate of a predetermined micromotion system agree in advance that the arbitrator would not confine his evaluation to the methodology or principles of the plan. He must be left free to get his information from all sources.

The place of the Industrial Engineer in arbitration of production standards has arisen in two significant cases. Case #1 was the Ford Motor Company to which reference has been made, and Case #2 is the IUE-Westinghouse case which is still in the process of being determined. The method used in the Ford Motor case was that the union retained its own expert engineer and the firm designated its expert engineer. The two engineers constituted a panel to choose a third lay member who would be able to resolve any dispute that might arise between the experts. The IUE-Westinghouse agreement called for the designation by both parties of an impartial engineer.

The choice of an impartial engineer in disputes of this nature offers very difficult problems. The reason is not too difficult to see. Any engineer who would be chosen by the parties in dispute is devoted to the highest principles of

[2] See Gomberg, William, *Trade Union Analysis of Time Study* (revised edition), 1954 (Prentice Hall). Ireson and Grant, *Handbook of Industrial Engineering*, section 17, 1954 (Prentice Hall).

WAGE INCENTIVES as a Managerial Tool

WILLIAM B. WOLF

Here is the first comprehensive study of wage incentives as a managerial tool. Concise and easy to read, it presents a balanced picture based on extensive case studies and a thorough understanding of the underlying logic governing both theory and practice. Included is a list of sound principles as a guide for administrators.

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integrity and is by necessity bound by the particular set of procedures in this controversial field to which he has pledged himself in his writings and research. If he remained without any opinions in this highly fluid field of ours, he would likely be a person either without any courage or without any knowledge. A much wiser role for the engineer would be to use his advocacy skills on behalf of his clients and, in the best tradition of our democracy, let the intelligent layman choose between the experts.

An illustration from another field will illustrate what is meant. During World War II, a great controversy arose in the synthetic rubber program between the petroleum chemists and the grain alcohol chemists over what procedure would yield the most promising results. Obviously, no chemist who was an expert in this area could be qualified to resolve this dispute. His very training and interest immunized him against impartiality. Eventually, the problem had to be resolved by a choice between the two contending groups by government lay administrators.

The status of job evaluation as a subject for collective bargaining has been long established. The latest decision in a number of cases that have been heard by the NLRB was handed down August 16, 1955. It involved a case between the Forge and Machine Workers Industrial Union and the Taylor Forge Pipe Works. The trial examiner found that the employer had refused to bargain with the union by refusing during collective bargaining negotiations to furnish the union with job evaluation point schedules. Although this decision clearly spells out the nature of the union's equity in this procedure, the principal question remains to what extent do unions find job evaluation a useful collective bargaining tool? The points of view that were current in the labor movement at the end of World War II in 1946 were clearly brought out in a conference of trade union technicians held under the auspices of the University of Chicago. There was lengthy debate that received wide-spread publicity at that time about whether or not job evaluation could be used as a collective bargaining tool. This debate was pretty well settled by the steel workers' adoption of a job evaluation scheme to govern the relationship between itself and the U. S. Steel Corporation. Many problems have arisen under the administration of the plan, but, by and large, it remains viable and active.

Job Classification

Another interesting case involves the fate of the Southern California aircraft industry plan. This was the plan that was set up during World War II to govern the classification of jobs in the fast growing aircraft industry. Clark Kerr and Lloyd Fisher described back in 1950 in detail the problems that arose under the administration of this plan. They stated, "The most difficult and pervasive problem in the administration of job description and evaluation in the Pacific Coast aircraft industry arose from the frequent conflicts between measures of external and measures of internal equity. The price of a job in the market is one well-established measure of its worth. The conflicts between these different standards made for continuous obstacles to the consistent administration of the plan. . . ." It was discovered both in Southern California and in Seattle that the plan overvalued skill in relation to the factors of job disutility, such as job conditions and physical application.

The United Auto Workers is presently engaged in negotiations with the Southern aircraft industry. A principal subject for discussion is the operation of the Southern California aircraft industry job evaluation plan. The U.A.W. found itself confronted with a problem opposite to that posed by Fisher and Kerr. Their problem was not the disutility of the jobs but the ceiling that the plan imposed upon skill and educational requirements. The increasing complexities of plane manufacture had led to educational and skill job requirements far in excess of those anticipated in the Southern California industry plan. The company had attempted to contain these skills within the existing plan by decreasing the step increments in points for each additional year of education required. For example, if three years of education called for 30 points—10 points per year—four years of education would call for 35 points, the fourth year being valued at 5 points. A high-powered brief was prepared to disclose the inequities of the plan. The company has agreed that the old Southern California aircraft plan has become obsolete in many respects, and both parties are now engaged in developing a relative wage payment plan better suited to current operating problems.

The United Automobile Workers have negotiated a new agreement with the North American Aviation Corporation, effective March 19, 1956. A new Article XVI, Section 3, calls for the designation of three members by the Union and three men by the company to investigate and agree upon a new or modified wage plan. It will be interesting to watch what develops out of the Board's deliberations during the course of the contract.

Just where does this leave job evaluation as a technique in the determination of relative wages within a plant? It is just one factor among others that will determine relative wages within a plant. By and large, the attitude of the labor movement in the field of Industrial Engineering can be described by an old admonition of John R. Commons, "Use the expert but never surrender to his tyranny."

CONFERENCE AND CONVENTION

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PLAN NOW TO ATTEND

Symbolic Logic: A Summary of the Subject and its Application to Industrial Engineering

By Sanford S. Ackerman

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A major aim of anyone engaged in a pure or applied science is to state propositions clearly and describe systems without ambiguity or the possibility of misinterpretation. Ordinary language is at best a difficult medium through which complicated propositions may be concisely expressed, and it fails miserably when relationships are mathematically or logically complex. Early Egyptian mathematicians struggled with the problem of what number plus one-fifth of itself equals twenty-one for several hundred years (8). They had no symbols for digits or algebraic operators; and, therefore, had to state the problem and attempt its solution using only words. The modern mathematician uses a formal system of digits, symbols, and operator notation to free himself of the encumbrances of words. It is apparent that some method of expression is needed to free the scientist from the tyranny of words and permit him to express propositions and describe complex systems in a rigorous manner, analogous to the way he can express mathematical ideas.

Symbolic logic is a means of expressing verbal propositions and statements of relationships between propositions in a concise and unambiguous form. The manipulation of propositions stated in symbolic form is performed by methods of Boolean algebra. It is the object of this paper to present the concept of the calculus of propositions—the exposition of verbal statements and their relationships in symbolic form—and Boolean algebra—the algebra of classes.

The uses of logic, like the uses of mathematics, cannot be limited to specific applications in a particular field. Just as the same differential equation can describe the mechanical vibrations of a physical system or the flow of electricity in a circuit, a symbolic sentence can describe the conditions of a contract or the operation of a computer element. Some of the examples of applications will be presented to show the manner in which symbolic logic can be used as an analytical method, with the inference that a substitution of some element of the industrial scene for the subject of the example can make the technique applicable to particular situations in Industrial Engineering.

In 1854, George Boole, an English mathematician, wrote the treatise, "An Investigation of The Laws of Thought, on which are Founded the Mathematical Theories of Logic and Probabilities" (3). He proposed a system by which propositions could be represented by symbols and manipulated to draw logical conclusions. Boole's original symbolism has been modified and extended since that original publication. In 1913, Alfred North Whitehead and Bertrand Russell, using the somewhat more complicated notation of Giuseppe Peano, an Italian mathematician, wrote the monumental work, "Principia Mathematica," in which they attempted to explore the logical foundations of mathematics, asserting that mathematics was in reality a branch of the more primary discipline, logic (8). For the most part, however, formal symbolic logic remained an academic pursuit without application in the engineering or business worlds. The first reported non-academic application of symbolic logic was by Edward C. Berkely at the Prudential Life Insurance Company in 1936 (8). Using symbolic logic, he examined the profusion of complicated rules governing the payment of premiums, and discovered that there were conflicts in the rules. An investigation of the files revealed that there were cases which had been handled under the conflicting rules. Since then, symbolic logic has been used to find ambiguities in contracts, and has found extensive application in the design of computer circuits (7).

Symbolic Logic and Boolean Algebra

Before proceeding further, it is desirable that the reader acquaint himself with the basic laws and definitions of Boolean algebra, and with the use of logical symbolism. Operator notation is not standardized; therefore, as each symbol is defined in the manner it is used in this paper, alternate forms are shown alongside in parentheses.

A set, or class, represents all elements lying within the specified bound which defines the set. Boolean algebra is an algebra of sets or classes of elements which have the properties described below (2):

1. Two binary operations, cup and cap,
   $\cup$ – Cup ($+$, $\vee$); $A \cup B$ reads, "A or B, or both," (Union)
   $\cap$ – Cap ($\times$, $\wedge$); $A \cap B$ reads, "both A and B," (Intersection)
   which satisfy the following laws:
   Indempotent: $A \cap A = A$, and $A \cup A = A$ (from which follows, $A^n = A$)
   Commutative: $A \cap B = B \cap A$, and $A \cup B = B \cup A$

Associative: $A \cap (B \cap C) = (A \cap B) \cap C$, and $A \cup (B \cup C) = (A \cup B) \cup C$

Distributive: $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$, and $A \cup (B \cap C) = (A \cup B) \cap (A \cup C)$

2. Two elements 0 and 1, which are universal bounds and satisfy the laws of union and intersection; i.e., $0 \leq A \leq 1$ for all A (Universal Bounds). $0 \leq A \leq 1$ reads, "the null set is contained in A is contained in the universal set.

$0 \cap A = 0$, and $1 \cap A = A$ (Intersection)

$0 \cup A = A$, and $1 \cup A = 1$ (Union)

These relationships are more easily understood with the aid of Venn's Diagram;

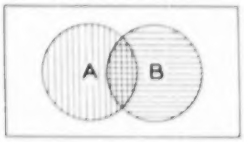


FIG. 1

Everything within the bound = the universal set = 1. $A \cup B$ (read, "union of A and B") = everything that is either A or B, or both; i.e., the areas covered by vertical lines, horizontal lines, and cross-hatching. $A \cap B$ (read, "intersection of A and B") = the area covered by cross-hatching. 0 = the null set; i.e., that set which contains nothing.

3. A unary operation of complementation which obeys the complementary, dualization, and involution laws;

$A \cap A' = 0$, and $A \cup A' = 1$ (Complementarity)

$(A \cup B)' = A' \cap B'$, and (Dualization)

$(A \cap B)' = A' \cup B'$

$(A')' = A$ (Involution)

A' reads, "not A." $'$ and $\sim$ are the symbols of negation. The dualization law may be stated in general as: The "not" of a polynomial may be found by taking the "not" of each term, and then interchanging cup and cap operators.

The following are some examples of manipulation of logical expressions (7):

(a) $A \cup (A \cap B) = A \cap (1 \cup B)$
$= A \cap 1$
$= A$

(b) $A \cap (A \cup B) = (A \cap A) \cup (A \cap B)$
$= A \cup (A \cap B)$
$= A$ (from a)

(c) $(A' \cap B') \cap (A \cap B)' = (A' \cap B') \cap (A' \cup B')$
$= (A' \cap A' \cap B') \cup (A' \cap B' \cap B')$
$= (A' \cap B') \cup (A' \cap B')$
$= A' \cap B'$

(d) $A \cup (A' \cap B) = [(A \cup A' \cap B')']'$
$= [A' \cap (A \cup B)]'$
$= [A' \cap A \cup A' \cap B]'$
$= [0 \cup (A' \cap B')]'$
$= A \cup B$

(e) $(A \cap B) \cup (B' \cap C') \cup (A \cap C') = (A \cap B) \cup (B' \cap C') \cap (B \cup B')$
$= (A \cap B) \cup (B' \cap C') \cup (A \cap B \cap C') \cup (A \cap B' \cap C')$
$= [(A \cap B) \cup (A \cap B \cap C')] \cup [(B' \cap C') \cup (B' \cap C' \cap A)]$
$= [(A \cap B) \cap (1 \cup C')] \cup [(B' \cap C') \cap (1 \cup A)]$
$= (A \cap B) \cup (B' \cap C')$

The above manipulations may be more easily followed when the cup and cap operators are thought of as the addition (+) and multiplication ($\times$) signs, respectively, of ordinary algebra, for which cup and cap are somewhat analogous.

The translation of ordinary language to symbolic form requires the interpretation of the above operators, and the definition of two more symbols. In a verbal context, "$A \cup B$" denotes the statement, "that which is either A, or B, or both." "$A \cap B$" denotes the statement, "that which is both A and B." "A'" denotes the statement, "not A," or, "it is not true that A. . . .". The first type of statement is disjunction, the second conjunction, and the third, negation. Another form of statement is, "$A \rightarrow B$" (or "$A \supset B$"); i.e., "if A, then B." This form is described as conditional, or a statement of material implication. Equivalence is shown as, "$A \equiv B$" (or "$A \leftrightarrow B$"), which reads, "A if, and only if B," or, "A is equivalent to B."[1] Material implication may also be expressed in terms of other operators for purposes of manipulation: $A \rightarrow B = A' \cup B$.

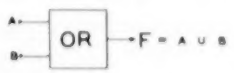
It is sometimes of interest to determine the truth or falsity of an entire statement when the constituent elements take on all possible combinations of truth and falsity. A convenient graphical representation is the truth table. Shown below are truth tables for conjunction, disjunction, material implication, and equivalence.

A	B	A ∩ B	A ∪ B	A → B	A ≡ B
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

For instance, given the statement $(A \cap B) \rightarrow (C \cup D)$, and the values A true, B, C, and D false, find the truth value of the entire statement. For the stated values in the table above, $(A \cap B)$ is false and $(C \cup D)$ is false. The given statement may now be thought of as an equivalent statement $E \rightarrow F$ where E and F are both false. For these values in the table, it is seen that the value of the whole expression is true.

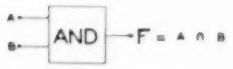
Applications

It is possible to design entire computing circuits by means of logical equations. "Black boxes" representing basic switching functions are defined as follows:



"or"—A signal F is transmitted when a signal is detected at either a or b, or both; i.e., $F = a \cup b$.

[1] The reader should note that some of these interpretations are only for ease of conception. A more rigorous interpretation is required when complex relationships are treated. See (9), page 93.



"and"—A signal F is transmitted when a signal is detected at a and b; i.e., $F = a \cap b$.

"not"—A signal F is transmitted when no signal is detected at a; i.e., $F = a'$.

Consider the following problem: From three inputs, A, B, and C, an output is desired when no input is detected, when only b is detected, and when only c is detected. The three conditions may be stated symbolically as,

$$F_1 = A' \cap B' \cap C',$$
$$F_2 = A' \cap B \cap C', \quad \text{and}$$
$$F_3 = A' \cap B' \cap C.$$

The entire problem may now be stated as,

$$F = F_1 \cup F_2 \cup F_3$$
$$= (A' \cap B' \cap C') \cup (A' \cap B \cap C') \cup (A' \cap B' \cap C)$$

This expression may be expressed in any one of the following ways:

$$\begin{aligned}
&(a) \quad F = A' \cap (B' \cup C') \\
&(b) \quad\;\; = (A' \cap B') \cup (A' \cap C') \\
&(c) \quad\;\; = (A \cup B)' \cup (A \cup C)' \\
&(d) \quad\;\; = [(A \cup B) \cap (A \cup C)]' \\
&(e) \quad\;\; = A' \cap (B \cap C)' \\
&(f) \quad\;\; = [A \cup (B \cap C)]',
\end{aligned}$$

each of which satisfies the stated conditions (7). The circuits described by these equations are pictured in Figure 2. Each one accomplished the desired result, but it is obvious that all are not of equal complexity.

This example demonstrates how a proposed system can be described symbolically, its logical description manipulated to yield alternative solutions, and those solutions "translated" into systems which meet the requirements stated originally.

Symbolic logic may also be applied to the resolution of complicated verbal relationships; e.g., insurance policy and contract stipulations. Two examples of this type of application follow. The first is from a book on logic by Lewis Caroll (8).

No kitten that loves fish is unteachable. No kitten without a tail will play with a gorilla. Kittens with whiskers always love fish. No teachable kitten has green eyes. No kittens have tails unless they have whiskers.

Will green-eyed kittens play with a gorilla? If we agree that the complement of each of the foregoing statements is also true, we may resolve the problem as follows: The elements are first defined by symbols: Let kittens which:

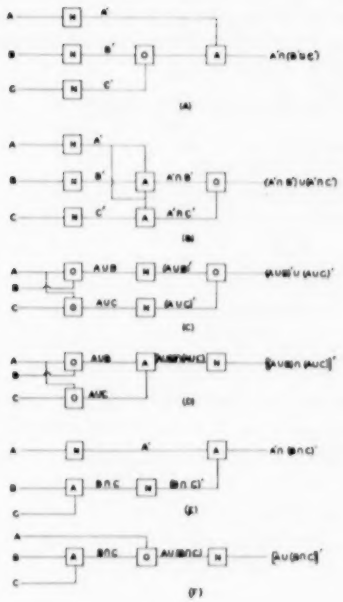


Fig. 2

love fish = b
are teachable = c
have tails = d
will play with a gorilla = e
have whiskers = f
have green eyes = g,

and the verbal conditions written as symbolic sentences[2]

1. $b \rightarrow c$ or $c' \rightarrow b'$
2. $e \rightarrow d$ or $d' \rightarrow e'$
3. $f \rightarrow b$ or $b' \rightarrow f'$
4. $g \rightarrow c'$
5. $d \rightarrow f$ or $f' \rightarrow d'$

Question: $g \rightarrow e$?

$$g \rightarrow c' \rightarrow b' \rightarrow f' \rightarrow d' \rightarrow e' \;\therefore\; g \rightarrow e'$$
$$4. \quad 1. \quad 3. \quad 5. \quad 2.$$

which says, "if a kitten has green eyes, then he will not play with a gorilla."

The previous example may be solved by carefully rewriting and rearranging the original relationships in verbal form. However, relationships are often confusing and complex to a degree which makes solution impossible by methods of verbal reasoning. Consider the following:

If a mathematician does not have to wait 20 minutes for a bus, then he either likes Mozart in the morning or whiskey at night, but not both. If a man likes whiskey at night, then he either likes Mozart in the morning and does not have to wait 20 minutes for a bus, or he does not like Mozart in the morning and has to wait 20 minutes for a bus or else he is no mathematician. If a man likes Mozart in the morning and does not have to wait 20 minutes for a bus, then he likes whiskey at night. If a mathematician likes Mozart in the morning, he either likes whiskey at night or has to

[2] The usual convention of logicians to use capital and lower case letters to denote statements and sets, respectively, is not adhered to in this paper.

wait 20 minutes for a bus; conversely, if he likes whiskey at night and has to wait 20 minutes for a bus he is a mathematician—if he likes Mozart in the morning. When does a mathematician wait 20 minutes for a bus (8)?

Proceeding as in the previous problem: A man who:

is a mathematician = A
likes whiskey at night = B
likes Mozart in the morning = C
waits 20 minutes for a bus = D
(a) $A \cap D' \rightarrow (B \cup C) \cap (B \cap C)'$
(b) $B \rightarrow (C \cap D') \cup (C' \cap D) \cup A'$
(c) $C \cap D' \rightarrow B$
(d) $A \cap C \rightarrow (B \cup D)$
(e) $B \cap D \rightarrow (C \rightarrow A)$

When a mathematician waits 20 minutes for a bus, it is equivalent to saying that A and D are true. If a truth table is constructed to show how the truth values of the problem statements vary for all possible combinations of truth values of B and C, the solution of the problem may be found by choosing those values of B and C for which all the problem statements are true; i.e., the conditions of A, B, C, and D which define the situation in which a mathematician waits 20 minutes for a bus.

A	B	C	D	a	b	c	d	e
T	T	T	T	T	F			
T	F	T	T	T	T	T	T	T
T	T	F	T	T	T	T	T	T
T	F	F	T	T	T	T	T	T

The three solutions say, $A \cap D \rightarrow (B' \cap C) \cup (B' \cap C') \cup (B \cap C')$ which reduces to, $A \cap D \rightarrow B' \cup C'$. The verbal statement of the solution is, "a mathematician waits 20 minutes for a bus when he does not like whiskey at night, or when he does not like Mozart in the morning, or both."

The possible complexity of the language problem is evident from the relative difficulties of the first and second examples. The extreme difficulty of finding conflicts in lengthy and complex legal documents, or in industrial specifications by verbal methods indicates that symbolic logic is a tool worthy of consideration for application in this area.

Boolean algebra is an algebra of classes, and, therefore, a useful method for solution of problems involving numerical classifications. Consider the following example from the joint associateship examination for actuaries, 1935: Certain data obtained from a study of a group of 1000 employees in a cotton mill as to their race, sex, and marital status were unofficially reported as follows: 525 colored lives; 312 male lives; 470 married lives; 42 colored males; 147 married colored; 86 married males; 25 married colored males. Are the data consistent? Let $N(A)$ denote the number of elements in class A. From the definition of union and intersection, the operator N has the property

$$N(A \cup B) = N(A) + N(B) - N(A \cap B).$$

Let:

c = colored lives
m = male lives
w = married lives

Using the property of the operator twice,

$$\begin{aligned} N(c \cup m \cup w) &= N(c) + N(c \cup w) - N[(c \cap m) \cup (c \cap w)] \\ &= N(c) + N(m) + N(w) - N(m \cap w) - \\ &\quad N(c \cap m) - N(c \cap w) + N(c \cap m \cap w) \end{aligned}$$

Substituting from the above data,

$$= 525 + 312 + 470 - 42 - 147 - 86 + 25 = 1057$$

For the conditions to be fulfilled, there would have to be 1057 employees. Since there are only 1000 employees, the data are inconsistent (2).

The above examples of applications of symbolic logic have shown how relatively simple verbal relationships which would be extremely difficult to manipulate and simplify by using ordinary language, can be handled easily when symbolic logic is used. However, when problems are considerably more complex, and the number of interrelationships grow, the task of manipulating logical equations and deriving truth tables reaches formidable proportions. Mechanical and electrical devices have been built to test symbolic logic sentences (5). One class of these could be called logical analog computers. For instance, a simple analog for the sentence $A \rightarrow (B \cap C) \cup D$ could be constructed from relays as shown in Figure 3.

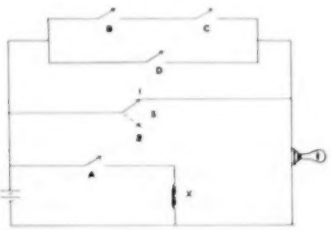


FIG. 3

The switch S is excited by coil X; it is in position 1 except when X is energized by A being closed. A, B, C, D, and E are relays whose coils are energized when the value of the corresponding term is "true." E.g., take the case of A false, B true, C false, and D false. Relay B is closed; A, C, and D are open; switch S is in position 1; and the bulb lights—indicating that the sentence is true for the given truth values of the constituents. An entire truth table for this logical sentence can be generated by systematically trying all the combinations of constituent truth values. General purpose logical analog computers could be constructed of banks of relays, or electronic switching circuits. The design of these analogs is the inverse of the logical design of computer elements mentioned earlier.

A method of generating truth tables from logical sentences, using a digital computer, is reported in (1). Programs which generate truth values for logical sentences of two variables in any of the forms—conjunction, disjunction, material implication, equivalence, and negation—

are used on "nested" logical sentences to generate truth tables of sentences of any length or complexity. This nesting technique is shown as follows (1):

$$((p_1 \rightarrow p_0) \cap (((p_0 \cap p_1) \cap p_2') \rightarrow p_2)) \cap ((p_2 \rightarrow p_1) \cap (p_0' \rightarrow p_3))$$

$$\begin{aligned} a_1 &= (p_1 \rightarrow p_0) & b_1 &= (a_5 \cap a_2) \\ a_2 &= p_2' & b_2 &= (a_4 \rightarrow a_3) \\ a_3 &= (p_2 \rightarrow p_1) & c_1 &= (b_2 \cap a_3) \\ a_4 &= p_0' & c_2 &= (b_1 \rightarrow p_2) \\ a_5 &= (p_0 \cap p_1) & d_1 &= (c_2 \cap a_1) \\ & & e_1 &= (d_1 \cap c_1) \end{aligned}$$

The computer may now compute truth values for the whole sentence by finding the truth values for the "nested" two-variable sentences.

Another problem involving the partial generation of a truth table is that of finding only those values of the variables which are compatible with the statement of the problem. As an example of how a problem of this sort could be handled on a digital computer, the following illustration is presented. A part is manufactured by three machining operations, one in department I, one in department II, and one in department III. Department I has five kinds of machines which can be used, II has six, and III has three. However, because of scheduling problems and property changes in the part caused by using a particular machine in a previous department, there are restrictions on the sequence of machines which may be used to produce an acceptable part. The departments and machines are represented below:

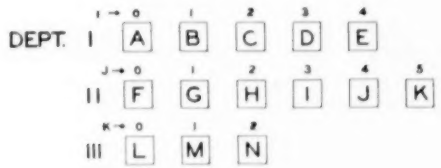


Fig. 4

Stated symbolically, the manufacturing process is:

$$\begin{aligned} \text{I} \cap \text{II} \cap \text{III} = {} & (A \cup B \cup C \cup D \cup E) \\ & \cap (F \cup G \cup H \cup I \cup J \cup K) \cap (L \cup M \cup N) \end{aligned}$$

(Which reads, the combination of processes in departments I, II, and III is equivalent to the use of A or B or C or D or E; and the use of F or G or H or I or J or K; and the use of L or M or N.) A series of conditions in the form $A \rightarrow B' \cap C' \cap D' \cap E'$ are written, their total effect being that the process is limited to the use of one and only one machine per department. The restrictions on the use of particular machines in sequence have been determined from shop studies, and are as follows:[3]

$$\begin{aligned} A &\rightarrow I' \cap J' \cap K' \cap L' \\ B &\rightarrow J' \cap K' \cap N' \\ C &\rightarrow F' \cap J' \cap M' \\ D &\rightarrow F' \cap H' \cap M' \\ E &\rightarrow F' \cap G' \cap I' \cap J' \cap K' \cap L' \cap M' \\ F &\rightarrow C' \cap D' \cap E' \cap N' \\ G &\rightarrow E' \cap M' \cap N' \\ H &\rightarrow D' \\ I &\rightarrow A' \cap E' \cap L' \cap M' \\ J &\rightarrow A' \cap B' \cap C' \cap L' \\ K &\rightarrow A' \cap B' \cap E' \cap M' \\ L &\rightarrow A' \cap E' \cap H' \\ M &\rightarrow C' \cap D' \cap E' \cap G' \cap I' \cap K' \\ N &\rightarrow B' \cap F' \cap G' \end{aligned}$$

The restrictions generate a truth table, which can be stored in the memory of a computer in the following manner: (See Figure 5.) The i, j, k, notation is shown in the representation of the departments and machines above. The computer is then instructed by the program of Figure 6. The computer will then print those sequences of machines on which acceptable parts may be produced.

The application of digital and analog computers to the solution of problems in symbolic logic extends the usefulness of the method greatly. E.g., a problem of the type just discussed could have ten machines in each department, and seven departments without using all the memory of a computer of the IBM 650 type. This represents a total of ten million possible sequences. Although the size of symbolic logic problems solvable on a digital computer is ultimately limited by the memory storage capacity of the computer, the problems lying within this limit are not trivial.

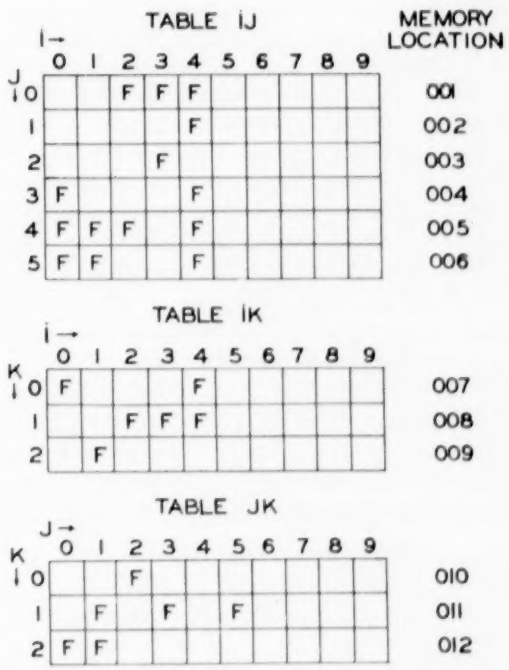


Fig. 5

[3] These restrictions are from a problem in (4).

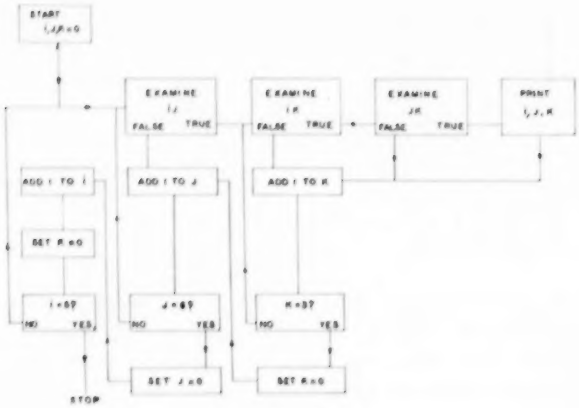


FIG. 6

In a recent article (6), it has been suggested that automation has been applied in manufacturing only in obvious situations where there is a demand for a high-production item. The author of the article suggests that additional applications for automation exist where a single sub-assembly or part is common to a variety of different items being produced. Further, a minor redesign of similar parts could yield a standard part which could be used on a large number of items. However, the identification of similar parts, or rather, parts which perform similar functional requirements, is a difficult task in a complex industrial situation. Symbolic logic can be applied in these circumstances to reduce the functional requirements of each part to concise logical sentences. Once stated in symbolic form, each functional requirement, which represents a part or a designer's need for a part, can be compared to tabulated functional requirements, which represent standard parts being made or which are available. Consider the following hypothetical example: A company making business machines uses a large variety of springs. The total number of springs used is extremely large, but the quantity of each variety is too small to permit an economical use of automation in manufacture. It is suspected that the large variety used is partly due to the fact that in situations where a number of different springs would satisfy the functional requirements equally well, one spring is specified by the designer, and from that point forward in the design and development procedure, the original functional requirements are forgotten, and only that one spring is considered for the job. To find opportunities for automation, the functional needs of each situation where a spring is required are stated symbolically.

a_1 = Spring constant k, 1 ± 1
a_2 = Spring constant k, 3 ± 1
a_3 = Spring constant k, etc., for the entire range of requirements.
b_1 = Length, $0.25'' \pm 0.125''$
b_2 = Length $0.5'' \pm 0.125''$
b_3 = etc., for the entire range of length requirements.
c_1 = etc., for all the classifications of descriptions needed to completely define all the functional requirements of a spring.

The functional requirements of any situation which calls for a spring may now be stated in a logical sentence; e.g., $(a_1 \cup a_2 \cup a_3) \cap (b_3 \cup b_4) \cap (c_5)$, etc. The logical sentences may be coded and punched on IBM cards. The problem then reduces to an ordinary collation procedure. In this manner, all the functional requirements which overlap enough to permit the use of one standard part may be identified; and if the demand for that standard part is sufficient, automated machinery for its production may be economically feasible. In addition, all the standard springs offered by vendors can be described by the same symbols, so that the collator can find what standard commercial springs will meet the functional requirements. Should automation prove impractical, this method will also show where there are opportunities for decreasing the number of different springs in inventory, and possibilities to buy more economical lot sizes.

Descriptions of the operating states of components of complex systems may be written in the same manner that ranges of numerical values where represented by symbols in the last example. Using these symbols, the interrelationships of components may be described in logical sentences, and these combined to describe the action of the system when a component's operating state deviates from the performance standard. The logical description of the system also represents the analog of a control mechanism which will alter other components of the system to compensate for that deviation. If the complex system is a business organization, and it is not beyond the realm of reason to describe the operation of an organization of humans symbolically, then the logical description is the analog of a set of rules or policies which govern the behavior of the organization such that it operates in a manner which will insure that the objectives of the organization as a whole are best served.

Conclusion

At this point, the reader may wonder if some of the solutions to suggested applications of symbolic logic are merely dressed-up versions of common sense or ordinary engineering procedure, and in reality a solution could be obtained in the same manner by someone who knew nothing about formal logic. The answer to this query lies in the previously stated definition of symbolic logic. It is a means of clearly expressing verbal propositions and their relationships in symbolic form. Someone who knows nothing of formal logic may unknowingly use elementary forms of that method and solve problems. This, however, does not detract from the dignity or usefulness of a formal system of symbolic logic and logical operations. The Egyptian mathematicians mentioned earlier knew little of the methods of a formal algebra, but managed to solve elementary problems. This certainly does not argue against algebra as a formal method, or its dignity as an element of mathematics.

In conclusion, a discussion of the advantages and disadvantages of symbolic logic as applied to practical situations is apropos.

An analysis of a complex situation can be made, and the results are in a concise and unambiguous form. Manipulation of component elements describing the system under consideration are performed in a rigorous manner, and conflicts and redundancies are disclosed and eliminated.

The disadvantages of symbolic logic in a practical situation are those of every model. A model is only an approximate description of a system, and as such, one can neither use it to exactly predict the behavior of the system, nor expect it to be valid when the system changes; i.e., when it is no longer the system for which the model was designed.

To compound this inherent limitation, the translation of complex verbal relationships into symbolic form is not simple. Logicians have grappled with the problem of translation since Boole's original dissertation, and the literature describing techniques is prodigious. The material covered here has been of the most elementary nature.

This logic is two-valued; i.e., each proposition may be either true or false. Probabilistic systems would require an extension of the method to include alternative solutions based on the probability of the stated relationships being true. This could conceivably be accomplished on digital computers by combining the solution of the logical problem with Monte Carlo or other statistical methods (4).

Symbolic logic has been presented as a tool for analysis of a practical situation. Its value lies in its ability to reduce complex problems to clear, concise terms. A knowledge of the subject, including its capabilities and limitations, is a valuable addition to engineering methodology.

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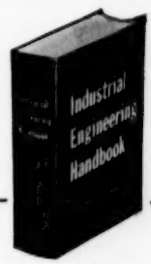

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This Profession—Industrial Engineering

By Paul E. Overcast

Industrial Engineer, Continental Can Company, Houston, Texas

Have you ever thought about being manager of an industrial plant or mill? No doubt you have, if you are one of many that spend their productive time in an industrial installation. But, have you ever wondered where plant managers were before they obtained that position? Did they hold the same position that you hold today? Or did they really start by sweeping the floor? Some did you know.

If you hold the position as head of an Industrial Engineering Department in industry, it might be interesting to know that one of the most frequent promotions for a person in that position is to plant manager. This was reported by 30 per cent of the plants replying in a recent nationwide investigation, as shown in Table 1. Another 15 per cent of the plants stated that when you are promoted, but not to plant manager, you will be made assistant plant manager. Overall, you have nearly a fifty-fifty possibility of being promoted to the higher echelon of plant management. This is the average for industry as a whole, disregarding the size of plants. The indications are even more favorable if your plant has, say, 500 to 1000 employees. These installations indicated 40 per cent of the promotions for heads of Industrial Engineering Departments would be to plant manager.

These data, as well as many others, some of which will be discussed in this article, were the result of an "Investigation of Industrial Engineering Functions and Personnel," (1) in which questionnaires were sent to all types of industries: metal, paper, chemical, electrical, etc., as well as to size plants above 250 employees. They were sent to top management and usually were completed by them. The questionnaire, composed of 36 questions, was rather broad in scope in that information was requested which heretofore was unavailable in accumulated form.

TABLE 1

Number of Plants That Indicated the Most Logical Promotion for a Head Industrial Engineer

Positions	Size of Plant			Total by Position	Per Cent
	Under 500	500 to 1000	Over 1000		
Plant Manager	7	13	12	32	29.9
Production Manager	9	4	11	24	22.4
Asst. Plant Manager	2	3	11	16	15.0
Line Supervisor	2	7	5	14	13.1
Div. I. E. Staff	2	3	5	10	9.3
Production Control Manager	0	2	2	4	3.7
Ind. Relations Manager	2	0	1	3	2.8
Management Staff	0	0	2	2	1.9
Head Engineer	1	1	0	2	1.9
Totals	25	33	49	107	100.0

Industrial Engineering Departments

This Profession—Industrial Engineering—is most definitely expanding. The number of companies reporting the establishment of Industrial Engineering Departments in the period from 1951 to 1955, compared with the fifteen previous years (1936–1940), shows a 278 per cent increase. Furthermore, the comments from those companies that do not have Industrial Engineering at present shows the trend for the future. As one Tennessee plant stated, "We are returning your questionnaire partially filled; we do not have an Industrial Engineering Department, but we need one now."

Out of the total plants indicating when the Industrial Engineering Department was established, only 12 per cent showed the department was in existence 25 years or more. Furthermore, better than 50 per cent of the plants indicated the department had been established in the last ten years.

Need for Industrial Engineers

At least two plants indicated they would have an Industrial Engineering Department if Industrial Engineers were available to fill the positions. The shortage of engineers is a problem realized by nearly everyone, but varies in acuteness. An attempt was made to gather some basic information on this by inserting a question directly related to the problem. This question, "What is the present need for Industrial Engineering in your Plant?" was extremely rewarding. Approximately three out of four plants stated that there were open positions in their plants for Industrial Engineers. If this data is analyzed by plant size, we find 85 per cent of the plants with 1000 employees or more indicating present need. Plants with 500 to 1000 employees stated needs on a comparable basis to the average for all plants, and plants with 500 or less employees indicating the lesser need.

Stating the need for Industrial Engineers is one thing, but as to how great the need, is another. Realistically, one would probably imagine that the larger the plant, the greater the need, and that is exactly what the data collected shows. For all plants, regardless of size, the average number of Industrial Engineers needed per plant is 3.4.

The need varies from 1.3 Industrial Engineers for plants under 500 employees to 4.6 for plants over 1000 employees, with the medium size plants (500 to 1000 employees) indicating 2.7. Actually, we can go one step further in pinpointing the need for Industrial Engineers and that would be as to the type of industry. The metal, food, tobacco, and electrical industries show a greater need than the average for all plants. By far, the industry indicating the largest need for Industrial Engineers was the electrical industry (9.3 additional Industrial Engineers per plant). On the other hand, the paper and petroleum industries indicated the smallest need, with both stating 2.0. Explanation of this is understandable, with the petroleum industry being relatively new for This Profession—Industrial Engineering.

The questionnaire was designed such that the key questions were followed by a related question, in order to interpret accurately the data supplied. This was the case when it was asked if the plants had difficulty obtaining qualified Industrial Engineers. This followed the question regarding their needs and proved very valuable. After noting the needs that have already been pointed out, it is not surprising that some plants answered this question with the words, "critical," and "none available." Also, it was not surprising that it illustrated the shortage of Industrial Engineers, but it was surprising when a company stated Industrial Engineers are less available than other engineers. Whether this is the case in particular areas only was not obtainable from the data.

The two other significant results were recorded from this question. First, several plants made it quite clear in their statements that Industrial Management graduates should not be substituted for Industrial Engineers. Second, many applicants are trying to fill vacant positions for which they are not *qualified* and consequently, are making a poor showing. It was rather humorous, though serious, when a Texas plant stated the personnel available to fill the vacant positions are so poorly qualified that they would not leave the women alone during working hours.

This brings us to another question which was asked, "What qualities are most essential in an Industrial Engineer?" The results of this question may be stated something like this: Industry wants a nearly perfect person, a person that has the traits of being tops in every respect, a person that can be a salesman, a promoter of good labor relations, have leadership plus, and be a gentleman. This Industrial Engineer also has to have initiative, sound judgment, be loyal and tactful, have common sense and imagination, and continue to have an open mind. Then we should add to this that the Industrial Engineer has an educational background training him to have analytical ability. There is little doubt that the sum of these qualities would result in a nearly perfect Industrial Engineer.

Industrial Engineering Functions

Perhaps the prime inquiry of the entire investigation was the question which involved the functions of industry for which the Industrial Engineering Departments are primarily responsible. The functions that were listed on the questionnaire included only those that are likely to be performed by Industrial Engineering Departments. It was not anticipated that the Industrial Engineering Departments would be reported exclusively responsible for the functions. On the contrary, the results of the tabulated replies indicated that other departments are more frequently responsible for performance of some of the functions. Those functions which were most frequently reported as being performed by the Industrial Engineering Departments were (A) time studies (94 per cent of total replies), (B) work simplification (91 per cent), (C) methods studies and analysis (88 per cent), (D) wage incentives (85 per cent), (E) materials handling (72 per cent), and (F) cost reduction (68 per cent). Five functions were reported to be the responsibility of the Industrial Engineering Departments by less than 15 per cent of the plants. Safety was reported assigned to Industrial Engineering by 4 per cent of the plants, quality control by 6 per cent, machine design by 8 per cent, and production control and purchasing analysis by 11 per cent. There is some question in the reliability of the results regarding purchasing analysis. A similar statement should also be made for operations research due to the interpretation of the function. Table 2 shows graphically the percentage of plants indicating that specific functions were the responsibility of the Industrial Engineering Department. It can be observed from the graph that the Industrial Engineering Department was reported responsible for nine of the twenty functions by more than half of the plants.

TABLE 2

Percentage Distribution of Departments Responsible for Various Functions in Plants with Industrial Engineering Departments

Functions	Departments							
	Accounting	Engineering Except I.E.	Executive	Industrial Engineering	Industrial Relations	Operating or Production	Production Control	Others
Administrative Procedures	11.5	—	51.4	27.0	3.8	3.8	—	2.5
Cost Analysis	41.5	2.0	4.0	48.5	—	4.0	—	—
Cost Reduction	8.6	4.4	5.5	68.5	—	13.0	—	—
Customer Estimating	25.0	8.8	—	34.0	—	—	—	32.2
Equipment Selection	—	55.0	8.5	28.0	—	8.5	—	—
Job Evaluation	—	—	1.0	50.0	47.0	2.0	—	—
Machine Utilization	—	8.0	—	60.0	—	18.0	11.0	3.0
Materials Handling	—	11.0	—	72.5	—	5.5	6.6	4.4
Methods	—	4.2	—	88.5	—	7.3	—	—
Operations Research	—	36.0	11.5	45.0	—	7.5	—	—
Planning & Scheduling	1.0	—	5.3	17.0	—	30.5	42.0	4.2
Plant Layout	—	39.0	2.2	54.3	—	4.5	—	—
Product Design	—	85.4	1.2	8.5	—	3.7	—	1.2
Production Control	—	—	4.3	11.0	—	40.4	43.2	1.1
Safety	—	3.0	—	4.3	74.0	8.7	—	10.0
Time Studies	—	1.9	—	94.4	—	3.7	—	—
Wage Incentives	—	1.5	—	85.0	7.5	6.0	—	—
Work Simplification	—	1.1	1.1	91.2	—	6.6	—	—

Though the questionnaire was principally intended for plants with Industrial Engineering Departments the opportunity was taken to inquire from plants without In-

TABLE 3

Number and Percentage of Plants Indicating Functions Performed by the Industrial Engineering Department That Are Most Important

Function	No. of Plants	Per Cent of Total
Standards	68	20.9
Methods	63	19.4
Cost Analysis	45	13.8
Cost Reduction	25	7.7
Plant Layout	24	7.4
Work Measurement	22	6.8
Job Evaluation	14	4.3
Machine Utilizations	13	4.0
Procedures	8	2.5
Work Simplification	8	2.5
Material Handling	8	2.5
Scheduling	5	1.5
Others	22	6.7
Total Indications	325	100.0

dustrial Engineering Departments as to the established department that was responsible for the functions normally considered belonging to Industrial Engineering. The results indicate that when the plant is without an Industrial Engineering Department, the functions are distributed among several departments, among which were Executive, Production, Industrial Relations, and Engineering. Of the nine functions previously mentioned as being the responsibility of Industrial Engineering when there was such a department, only two of the functions were the responsibility of one department more than 50 per cent of the time. These were Industrial Relations' responsibility for Job Evaluation (55 per cent) and Engineering's responsibility for plant layout (70 per cent). This indicates that when the plant is without an Industrial Engineering Department there is little standardization of assigning functions to departments throughout the plants.

As stated earlier, the questionnaire was designed with follow-up questions and it might be said it was purely for the accurate interpretation of the data. Since the prime question of the survey covered the functions that the Industrial Engineering Departments were performing, it was somewhat natural to ask these same departments what functions were the most important from their standpoint. Also, since these departments are assigned a number of basic functions in most plants, it was interesting to learn which of the functions the plants considered most important.

Work Measurement

There was a broad range among the plants in designating the most important function; however, the one Industrial Engineering function which is most important in industry is "standards." It was indicated by 21 per cent of the plants. Closely following with less than 2 per cent variation is "methods." Referring to Table 3, one can observe the remaining ranking and the significance between the most important functions and the functions that are the responsibility of the Industrial Engineering Departments.

Besides knowing that the Industrial Engineering Department nearly always was responsible for standards, it was important to know which work measurement techniques were utilized to obtain the information for the standards. In the past several years, there has been considerable discussion and writing regarding the work measurement techniques and methods used by Industrial Engineers. Consequently, to determine the use of work measurement by plants, several of the questions revolved around this important function. Ninety-six plants indicated that stop watch studies were used (34.5 per cent of total indications); seventy-six reported standard data was used (27.3 per cent); sixty plants reported work sampling was used (21.6 per cent); thirty-five plants stated MTM (12.6 per cent); and eleven plants indicated either micro-motion or BMT. Most of the plants indicated two or more work measurement techniques.

In addition, information supplied and calculated shows 40 per cent (an approximate average) of total Industrial Engineering time is utilized on work measurement. The plants' replies varied widely on this question and there were some indications that the 25 per cent and the 50 per cent categories were too readily indicated for completely accurate results.

This Profession—Industrial Engineering, is undoubtedly growing at a far faster pace than is the supply of qualified Industrial Engineers. An illustration of the magnitude of this problem may be obtained from the results of the question regarding the educational background of the people in the Industrial Engineering Departments.

Educational Background

The results obtained from the investigation for this question are shocking to say the least. Many of the Industrial Engineering Departments throughout industry are manned by personnel that are not formally educated and trained in Industrial Engineering. Of course, it is understandable that a degree in Industrial Engineering is not absolutely essential since some plants have training programs of their own for such purposes. However, from the results of these questions, one would be inclined to believe that this is one of the reasons why plants stated *qualified* Industrial Engineers are not available in sufficient numbers.

From a total number of 1015 employees in the Industrial Engineering Departments surveyed, 249 had a degree in Industrial Engineering (Table 4). This is less than 25 per cent of the personnel. Of the 249 Industrial Engineers, 16 indicated they also held advance degrees. Graduates of Business Administration accounted for 17.7 per cent of the personnel, mechanical engineers accounted for 10.7 per cent, and other college graduates accounted for 8.9 per cent. This leaves the largest category for personnel that are not college graduates (38 per cent). This is more than

the percentage of all engineers, Industrial and Mechanical, that are graduates. (Note: All figures exclude clerks and stenographers.)

As Table 4 shows, the size of the plants had little or no bearing on the distribution of the employees in the Industrial Engineering Departments. The only significant statement that can be made, is that the average percentage is not constant throughout industry. Closer analysis of the larger and more progressive plants (and companies) shows that their departments are manned by graduate Industrial Engineers a larger percentage of the time than other plants. This can probably be attributed to the tremendous recruiting programs these companies maintain.

TABLE 4

Distribution of Employees in Industrial Engineering Department According to Educational Background

Size of Plants	No. of Employees in Industrial Engineering Departments*	No. of Employees in Departments with:					
		B.S. in Ind. Engr.	M.S. in Ind. Engr.	Mech. Engr. Degrees	Bus. Adm. Degrees	Other College Degrees	No College Degrees
Under 500	48	19	1	4	6	2	16
500 thru 999	131	28	4	6	33	12	48
1000 thru 1999	145	27	3	9	28	15	63
2000 thru 2999	93	17	2	18	23	7	26
3000 thru 3999	155	38	2	8	16	11	80
4000 thru 6999	89	9	0	23	12	3	42
7000 thru 9999	249	54	2	39	34	35	85
Over 10,000	105	41	2	2	28	5	27
All Plants	1015	233	16	109	180	90	387

* Excluding Clerks and Stenographers.

Professional Registration

Professional registration among engineers has for many years been restricted to a very small percentage of the total. This is still true even after the drives placed in motion by many engineering organizations. The results obtained from this investigation show the Industrial Engineering profession has not increased the rate of registration among engineers. In fact, the results show the overall number of 43 registered engineers from the 358 engineers (Industrial and Mechanical) in the Industrial Engineering Departments. This is a ridiculously low 12.0 per cent.

Engineers, and this should include those in all engineering professions instead of just the Industrial Engineering profession, are failing to protect their professions by not registering. It is true that some states make it rather too difficult for engineers to become registered, but with continued effort on the part of our engineering organizations, this can be minimized. Industrial Engineering has a unique problem as the profession is not recognized by all states and territories, making it even more difficult for registration. This can and should definitely be overcome.

Wage Payment Plans

With two exceptions, plants that have wage incentives for hourly paid employees are also plants that have Industrial Engineering Departments. Hence, eighty-five per cent of wage incentives for hourly paid employees are developed through standards established by Industrial Engineering Departments. Less than 10 per cent of these wage incentives are based on past production records. The same may not be stated for supervisory incentive plans, however. In those plants where there was a supervisory incentive plan (37 per cent of the plants), the bases are plant profit, and production efficiency (54 and 37 per cent of replies, respectively). Results also revealed that 54 per cent of the plants extend the supervisory incentive plan to their Industrial Engineers.

The treatment of Industrial Engineering personnel varies tremendously with the plants and companies. For example, the question was asked, "Are your Industrial Engineers exempt under the Federal Wage and Hour Law?" then the question, "How are your engineers paid for overtime?" The results that were obtainable from the first question showed an overall indication of 84 per cent of the plants classified their Industrial Engineers as exempt. The per cent varied with the type of industry, although, in some industries the number of plants reporting were too few to be significant for an indication. The electrical industry showed that 64 per cent of their plants classified Industrial Engineers as exempt, whereas, the paper industry from an equal number of plants, showed 100 per cent. The metal industry showed 85 per cent, with the results coming from a sampling of the entire industry. Textile and chemical plants indicated 91 per cent and 90 per cent respectively.

One would think the methods of paying engineers for overtime could be predicted readily after understanding the results of the classification of engineers. This is not the case. Instead of paying compensation for overtime on a comparable basis to classification, results show 50 per cent of industry not paying any compensation to Industrial Engineers for overtime work. Of the 50 per cent that do pay compensation, 30 per cent allow one and one-half base pay, and 16 per cent allow the base pay rate. The remaining plants give equal time off. These results may be summarized by saying that it seems that some of the industries recognize that overtime work deserves compensation regardless of the law. (See Table 5.)

Professional Activities

Two other questions that have significance regarding the treatment of Industrial Engineers in industry relate to: (A) paying dues to professional societies, and (B) sending personnel to attend conferences, clinics, etc., to keep abreast with the profession.

Approximately 46 per cent of the plants stated the companies did pay dues to professional societies for Industrial Engineers. The size of the plant seems to have little or no bearing on the results of the question; however, the size of the company did show some variation. More plants from the smaller organizations indicated they pay the dues

TABLE 5

Number and Percentage of Plants That Indicated Industrial Engineers Are Allowed Compensation for Overtime

Type of Industry	Total No. of Plants	No. of Plants Indicating Overtime Compensation	Per Cent of Plants
Metal	40	21	52.5
Paper	11	1	9.1
Food	4	1	25.0
Wood	8	4	50.0
Textile	12	5	41.7
Tobacco	2	1	50.0
Chemical	20	13	65.0
Petroleum	2	0	0.0
Electrical	11	9	81.8
Miscellaneous	12	6	50.0
All Plants	122	61	50.0*

* This was distributed as follows: 31.5%—1½ Base; 13.6%—Straight Time; 4.9%—Same Amount of Time Off.

than those from the larger organizations. On the other hand, in regard to sending personnel to attend conferences, clinics, etc., the larger organizations participate to a greater extent than the smaller organizations. Overall, better than 30 per cent more plants (78 per cent) send Industrial Engineers to meetings and pay their fees, than pay dues for professional societies.

It is most commendable that a high percentage of companies send engineers to meetings and conferences, as this is indeed a logical place for educational institutions and industries to exchange ideas. It would be beneficial to both parties if more plants paid the dues to professional societies as their meetings are also very satisfactory in the exchanging of ideas. It is at this type of meeting that Industrial Engineers exchange ideas and thoughts among other members of their profession. There is hardly an equal method of keeping abreast of the profession.

In order to determine if the number of plants that pay dues to societies, and the number that send engineers to conferences, are independent, a statistical test with the use of the chi square statistic was applied to the results. It was calculated that there was no correlation at the 95 per cent level of significance and that the number of plants paying dues to societies and the number of plants sending engineers to conferences are independent.

Industrial Engineering Curricula

During the entire period of this investigation, the word "qualified" was emphasized by the plants. In order that colleges may meet industry's educational requirements, which they are anxious to do, the plants were asked to indicate the courses that should be added to, or emphasized in, the Industrial Engineering college curriculum to better equip or qualify the engineering graduates. There were a total of 36 different courses indicated by the plants. The course that was indicated by the largest number of plants (31 per cent) was labor relations. The second highest course (27 per cent) was work measurement, third (26 per cent) was accounting, fourth (25 per cent) was statistics, and fifth (23 per cent) was report writing. The next five courses were materials handling, mathematics, psychology, engineering economy, and economics.

It can be observed that with such courses as work measurement, accounting, statistics, and mathematics indicated among the most needed, the plants are realizing the serious handicap their Industrial Engineering Departments have without the service of educated and trained Industrial Engineers. As to how long these departments are going to have to continue without the service of educated and trained Industrial Engineers depends on both industry and education, as well as the individual engineer. This is true of the entire Engineering profession.

Industry, in many respects, as illustrated by the results of this investigation, is not helping to solve the problem to the extent possible. It has and is continuing to show the lack of an incentive for the potential engineer. For example, industry has allowed the average earnings of production workers to triple while allowing the average salary for engineers with ten years experience to be only $7850 per year. The gap in take-home pay between production workers and engineers is becoming so small that the incentive to become an educated and trained engineer is nearly eliminated from the financial standpoint. Discontent over professional status and the disappearance of individual relations between engineers and their employers are also cited as principal causes whereby industry is removing an important incentive. These policies adopted by industry are turning the engineer to unionization, reports the National Industrial Conference Board. The Board shows that 60,000 of America's engineers hold union cards and the number is increasing daily. It is questionable whether this trend will help to sell the potential engineer to become an educated and trained man and hence, fill the many positions that will be open in the industry of tomorrow.

REFERENCE

(1) Overcast, Paul E. and Bonds, B. H., "An Investigation of Industrial Engineering Functions and Personnel", Masters thesis, under the direction of Dr. J. T. Elrod, Chairman, Industrial Engineering Department, University of Houston.

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Toward a Theory of Job Design

By Louis E. Davis

Associate Professor of Industrial Engineering, University of California

Those who create, design or establish jobs (exclusive of tradition-determined jobs) are guided almost entirely by the following few criteria:

1. Economic considerations or hypotheses
2. Process considerations
3. Time or space considerations
4. Kinds of skills available and numbers of people available
5. Tools and equipment required
6. Union-management agreements
7. Custom or tradition

By relying on these narrow criteria we have designed jobs which have a host of disturbing secondary effects in terms of dissatisfaction, monotony, resistance and obstruction. In addition, designs of jobs have frequently failed to yield predicted results. Such failures to achieve anticipated results frequently have been laid to the "contrariness of human nature." This may be taken as another way of stating that, given the current state of knowledge, the effects of job designs cannot be estimated. In view of the engineering, economic, psychological and social consequences of job designs, the inability to predict the effectiveness of a particular design raises two fundamental questions:

1. What factors should guide the design of jobs?
2. What criteria should be used to evaluate the effectiveness of job designs?

There is little available information about the role of the job as industry has developed it in terms of its effects (economic, psychological, engineering, social, and other) on the formal production organization, social structure of the company, and the individual working on the job.

From the engineering standpoint, the design of the job affects productivity, the further subdivision of jobs, the development of automation, the effective design of plant, equipment, tools, and product, and in general the basic engineering concepts underlying the methods of organizing high volume or mass production.

From the economic (as well as engineering) standpoint, job design affects the concept of specialization of labor in terms of its effective use, total economic costs as well as currently used production cost measures, the efficient utilization of manpower and materials, and capital investment requirements.

From the psychological standpoint, the design of the job affects requirements for employees' aptitudes, skills and knowledge; employees' morale, motivation, satisfaction, and inter-personal relations; "meaningfulness" of work performed; acceptability of job changes, and transferability of skills.

From the social standpoint, job design affects the methods of organizing individuals and groups for work; status differences associated with jobs; social and organizational structure of the company; pattern and method of communication within the organization; flexibility of the individual, group, and organization in adapting to and accepting changes in jobs, products, or procedures.

Where the content of jobs has been manipulated or redesigned, within a given state of technology, in the direction of enlarging job size or responsibility, gains in productivity and morale as well as reduced costs have been reported. These results serve to illustrate the inability, from the standpoint of the classical method of job fractionation, to predict the consequences of job designs.

Such gains may possibly be explained as being derived from a resolution or diminution of conflict existing between the individual's motivational forces and his assigned work. This kind of conflict has been observed in a number of instances, and when present appears to have a deleterious effect upon productivity, costs, morale, social organization, etc. It is our hypothesis that many personal and productivity problems in industry stem directly from existing job designs.

As was indicated earlier, the area of job design is complex and multi-dimensional, involving organizational, technical, and personal dimensions. Job design may be conceived as the organization of the content of a job to satisfy the technical-organizational requirements of the work to be accomplished and the human requirements of the person performing the work.

Delineation of the Job Design Area

Some fundamental questions must be raised concerning the design of jobs and the effectiveness of performance on jobs of given design. It is difficult if not impossible at present to provide definitive answers concerning these questions. The questions can be divided into three groups, as follows:

1. What influence does job design have on effectiveness of an individual's performance as measured by

   a. productivity
   b. quality
   c. long-term costs

d. satisfaction
e. morale, etc.

2. What are the most effective methods of achieving optimum performance? This requires a consideration of the methods of design and specification of jobs, as compared with the methods of palliating the effects of given designs by various means internal and external to the content of the job itself. These considerations include determining the effectiveness of original job design as compared with after-the-fact alteration of jobs by means of job rotation, job enlargement, etc. The effectiveness of job design methods must also be compared with the alteration of factors external to the physical job, such as human relations programs, supervision and leadership, incentives, etc. Additionally, the question is raised as to when and to what extent correction of job designs should be undertaken, and who in the organization should be concerned with this activity. Although there appears to be competition for this activity between engineering and personnel departments, in actuality the activity at present is in a no-man's land between the two.

Insufficient data are available to permit management to make a decision concerning where, how, and by whom the activity is to be performed. Decisions concerning this are fundamental to the structural design and operation of the entire organization.

3. Can a theory of job design be developed and, if so, can it be expressed in terms of systematic methods in the form of guides and principles that can be used by engineers, personnel managers, supervisors and managers? Satisfying this need will require a comprehensive research program, concerned with:

a. the nature of job content as related to job performance, to aspiration, to perception of the individual's role in the organization
b. the interrelationships between the technical, organizational and personal requirements of each job
c. an evaluation of the organization's structural design theories and methods as related to the technical and personal requirements for effective performance on jobs
d. evaluation of the technical production theories and methods as related to the organizational and personal requirements for effective performance on jobs
e. an evaluation of the effectiveness of manipulating factors internal and external to job content and the boundary limitations of each.

Considering job design as creation and specification of job content, then it must be viewed as a design problem which raises the needs to:

a. identify boundaries and evaluate boundary conditions
b. identify factors operating and determine the effect of each
c. determine methods of estimating and controlling the factors operating
d. develop systematic design methods
e. develop methods of predicting consequences of design
f. develop methods of feed back to evaluate predictions and to make adjustments in design
g. develop criteria for evaluation (total economic cost measure)

Dimensions of Job Design Theory

A job design theory can best be conceptualized in a three-dimensional framework, namely, an organizational, technical, and personal framework. Within such a framework we may be able to move toward the development of a job-centered approach to job design. The technical dimension includes the factors involved in the production process, such as man-machine systems; work flow and scheduling; inspection and control systems; work methods; work performance (quality and quantity) standards; tool, equipment and product design; and plant layout. The organizational dimension includes those factors involved in the structure of the organization such as functional specialization, communication and coordination systems, number of hierarchical levels, number of sub-units, policies of delegation of authority and responsibility, management operational practices and policies, contractual agreements with unions, etc. The personal dimension includes such personal behavior influencing factors as executive, supervisory and employee abilities and skill levels in relation to requirements, personal and group motivation and attitudes, personality characteristics, interpersonal and group relations, identification with and perception of the organization, aspirations and rewards, participations, etc.

The job-centered approach, which is being conceptualized, gives consideration to the question of how job content can be organized to satisfy the needs of the technical process, of the organization, and of the individual worker in order to maximize economic productivity. In addition, this approach is based upon an hypothesis that there is an organization-worker-job interaction and that therefore a job cannot be designed independently of the process, worker, and organization variables. Changing any of these job design variables in isolation from the others may cause a decrease in economic productivity. In addition to the variables introduced by the technical process, the organization, and the person, the job-centered approach to job design requires the consideration of effects stemming from the interaction among the variables. The concept of interaction, although recognized and discussed for some time now as a significant factor in obtaining the goals of an organization, has not had adequate exploration, and consequently there is little available data about the variables related to job design phenomena.

Although the importance of individual aspects of the job-centered approach have been recognized for some time (such as job satisfaction, supervision, etc.) they have had small influence on job design practice. The probable reasons for this are (A) the lack of background necessary to utilize properly the available information on the part of those responsible for the design of jobs, (B) the available data have not been presented in the form of a job design theory, and (C) research conducted and results presented relate only to isolated aspects of the total worker-job problem.

Development of the Criterion: The Total Economic Cost Measurement

A good many of the difficulties, the inconsistencies of results and the opinions held concerning the design of jobs can be traced to the lack of a fundamental or true criterion. Before much progress can be made beyond the current status, an adequate criterion and sub-criteria will need to be developed. The lack of a criterion has led to job designs based upon the satisfaction of apparent economic criteria. The term 'apparent' is used because total costs are seldom considered, for there are little data available to provide yardsticks for total cost analysis of a given job design. This is indicated by the results obtained in a survey of job design practices in American industry (1). In this survey it was found that the design of industrial jobs is overwhelmingly influenced by the criterion of minimizing immediate cost of producing, that is, immediate costs of performing required operations. The usual indicator of achievement is taken to be minimum unit operation time. Designers of jobs see the criterion as being satisfied by the application of principles or guides that have been previously indicated. The acceptance of immediate costs or lowest apparent unit costs explains many current practices in job design as well as the inconsistencies in policy and programming that exist between the technical and the personnel sides of an organization.

We need to develop a total economic cost criterion which is concerned with the total cost of achieving productivity, and therefore includes relevant long-term charges in the form of money, time, growth, and psychological, social and cultural stress costs. One of the serious research problems that confronts us is to determine how total economic cost is to be measured in terms of economic, engineering, organizational, social, psychological, physiological, resource and human resource cost criteria.

The Need for Job Design Experimentation

The nature of job design research and experimentation should reflect the multi-dimensional character of the problem. The problem area is amenable to attack from many quarters, under certain requirements. Paramount among the requirements is that job content must be a central theme of all experimentation, with other variables included in various experimental designs. In addition, multi-dimensionality and interaction among variables calls for a problem-centered, research-team approach. Some of the dangers and defects of a compartmentalized approach have been indicated previously.

The nature of the problem area calls for on-the-scene rather than laboratory experimentation, with all of the attendant difficulties associated with field studies. The formulation of systematic criteria, hypotheses, dependent and independent variables, will require naturalistic studies in the form of observation of sample jobs. As assumptions and hypotheses are formulated, they may require empirical testing in the laboratory before use in the field.

Based upon previous work, intuition, and experience with a variety of business and industrial jobs, it is estimated that in terms of research results, the most fruitful point of initial study and application should be the semi-skilled job. Information and experience gained with this job class may permit research attention to move up in the job scale.

The types of data that will be required will call for research and field studies that may need to be conducted by Industrial Engineers, industrial psychologists, sociologists, anthropologists, economists, and researchers in personnel administration and industrial relations. Obtaining the data needed will require that studies be conducted that will range from determining and measuring "meaningfulness" as applied to operations, work methods, work groups and jobs, through the determination of long term total economic cost criteria, to the determination of the means of designing processes, systems, methods and product components in terms of job needs.

To answer the questions raised concerning the influence of job design on economic productivity and the means of achieving effective job designs, research will need to be undertaken in regard to the influence of job design on effectiveness of individual and organizational performance. Questions such as the following will need to be answered:

1. What influence does work content of a job have on effectiveness of performance on the job?
2. Can long term costs (total economic costs) for various job designs be determined? (Where high economic productivity provides minimum total long term cost)
3. What is the effect of work content on economic productivity?
4. What is the effect of work content on, and to what extent is it a determinant of, job satisfaction, morale, etc.?
5. Can comparative and systematic studies of the content and design of jobs be undertaken as between jobs with records of high and low economic productivity?

Systematic studies will need to be undertaken to compare the effectiveness of 'proper,' original job design with after-the-fact correction of jobs. Such studies will need to be undertaken for altering both internal job content factors by means of job rotation, job enlargement, etc. and external job factors such as supervision, incentives, etc.

To develop a theory of job design, a series of related research studies are required, which would provide the means of securing answers to such questions and of checking hypotheses such as the following:

Higher economic productivity (lower total costs) will result from specifying the work content of a job in the direction of:

1. Putting together tasks that constitute a "meaningful" unit of activity for the worker
2. Increasing the number of tasks in the job to cover a larger part of the process
3. Putting together tasks that are similar in technological content and skill demands
4. Putting together tasks that are sequentially related in the technical process
5. Providing a sequence of tasks or operations (or organiza-

tion of work) that provides a "meaningful" relationship between jobs
6. Putting together tasks that will include in a job each of the four types of work or activity inherent in productive work, namely: production (processing), auxiliary (supply, tooling), preparatory (set-up), and control (inspection)
7. Putting together tasks that include some final activities in the process or sub-process, or completion activities of a unit, part or product
8. Putting together tasks that permit completion of the part, product or process
9. Arranging the physical facilities and work flow so that the individual can identify the end use made of his work
10. Arranging the physical facilities so that identification and communication with prior and following work stations can take place as a matter of course
11. Putting together tasks and/or geographically locating the work station so as to facilitate involvement of the worker in his immediate work group
12. Putting together tasks so that the job requires increased worker responsibility for rate of output, quality, etc.
13. Putting together tasks so that the job provides the worker with increased control over his job, that is, that enlarges his scope of decision making, that permits choice of work methods, tools, work rate, etc.
14. Providing or permitting the development of work methods that are "meaningful" to the individual
15. Putting together tasks that permit the worker to perceive his relationship (the role he plays) to his organizational work unit and to the company as a whole
16. Putting together tasks that permit the worker to perceive the value of his contribution to the organization, to the community, to society
17. Putting together tasks or dividing the product so that the job is perceived as containing some degree of prestige within the organization or community
18. Dividing the product into units which will permit increased identification with the product
19. Putting together tasks that will result in a job requiring maximum utilization of the worker's skills and abilities
20. Dividing the product into the units (parts, components, documents) which are "meaningful" entities to the worker
21. Arranging the physical facilities and designing of communication networks so that feed-back on performance quantity and quality and on central information as to production needs takes place automatically and constantly
22. Providing "meaningful" measures of performance to the individual
23. Providing "meaningful" incentives to the individual

As indicated earlier, the end purposes of job design experimentation are the development of a theory of job design and of design guides or principles that flow from it. The availability of a theory and guides will permit the designer of jobs to evaluate job design alternatives, select optimal arrangements, and develop performance predictions for designs specified.

Industry's need to be involved in the development of effective job designs is acute at present and will continue to be so as our economy moves into the era of automation. Previously it was indicated that determining optimum job designs will be one of the major needs to be met by industry and business in order to maintain, and meet competitively, increasing levels of productivity. In addition, effective introduction and use of automation will create a very strong demand for job design, theory and principles. These will be needed to help ascertain what processes should be automated with reference to what workers can and cannot do better and to aid in the effective design of automation systems as regards the human links in the control of automated processes, particularly where essential data for making judgments cannot be furnished.

Future Practical Steps

Job design will require studies in industrial and business settings. Needed for the conduct of studies will be widely varying (in terms of size, organizational structure, process design, etc.) office, industrial and distribution facilities. A secondary source of data in job design studies will be the laboratory which will be needed for the development and testing of assumptions and hypotheses.

The immediate steps to be undertaken in a study of job design are those concerned with the identification of variables and their classification into criterion, dependent and independent variables; with the development of hypotheses; and with the identification of the effect on job designs on productivity, costs, human resource use, etc.

There are a number of avenues which may be fruitfully pursued in beginning a study of job design. The first is a review and study of traditional and historic job designs. By subjecting to careful scrutiny jobs that are highly valued and that yield a high degree of satisfaction, the factors associated with these jobs, and the methods of job design may yield important insights and hypotheses. In addition, and in contrast, the examination of low-valued and low-satisfaction yielding jobs and the factors associated with these would also be expected to yield significant insights.

Another approach that needs to be pursued bears upon current job design methods and is concerned with the investigation and evaluation of the job design process. This extension of an initial study previously undertaken would be concerned with the identification of methods of job design, responsibility for the design process, methods of installation of job designs, process decision variables, and a study of the designs in use in terms of labor availability, skill supply, capital investment per worker, organization size, equipment, requirements, etc.

A third avenue which must be pursued is concerned with criteria formulation. Needed is a determination of the means of establishing a minimum economic cost or maximum economic productivity criterion. Of concern here are such criteria as absenteeism, quality, productivity, turnover, and hidden costs such as organizational flexibility, employee grievances, etc. In addition there will need to be developed measures of the effectiveness of job designs. Such measures will be concerned with or account for criteria related to job conditions, job content, job methods, organizational structure, social organization, communication and feed-back, company-community relations, physical and physiological factors, attitudinal and motivational factors.

Another avenue to be pursued, based upon previously mentioned criteria development, the study of current job design methods, and traditional and historic job designs, will be the development of hypotheses to be tested in preparation for the formulation of a job design theory.

The goal of the immediate steps is the preparation for hypothesis testing or experimentation, permitting in the subsequent phases of study the development of job design theories. The goal, then, of the subsequent phases will be the development of job design theories. With such theories available, job design principles or guides can be extracted for the use of engineers, personnel administrators, supervisors, and management in the solution of the every day problems of developing job designs.

The payoff value that may be estimated of job design study will be extensive for the management sciences, engineering sciences, and social sciences. As concerns management, the availability of job design theories will have a strong bearing on organizational theories and organizational designs, on the design of reward systems, on the design of control systems, communication systems and the operation of a large part of the personnel administration function. In terms of engineering science, the availability of job design theories will have a strong bearing on the development of work conditions, control systems, operations, methods, jobs, etc. As concerns the social sciences in the industrial setting, the availability of job design theories will have a strong bearing upon the formulation of human relations programs and methods, and employee relations programs and methods, organizational methods, supervisory methods (embracing leadership methods), selection and placement of personnel, design of communication networks and reward systems, etc.

REFERENCE

(1) Davis, L. E., Canter, R. R. and Hoffman, J. F., "Current Job Design Criteria", *Journal of Industrial Engineering*, v. 6, n. 2, Mar. 1955, p. 5.

PRESIDENT'S MESSAGE

INTROSPECTION

By Gordon B. Carson

President, American Institute of Industrial Engineers, Inc.

Introspection has been condemned by some as a waste of time, destined to lead only to an inferiority complex in the mind of the self-analyst. But this is only a superficial part of the problem. True introspection goes deeper. Specifically, it is the action of looking under the surface. It implies the determination of the "why" behind the action which has taken place, and it should include an examination of the intellectual route by which we arrived at the present situation.

We, the members of the most recently organized and

integrated professional engineers' organization, must re-examine the route over which we have come. We must better understand where we are going and the achievements which must be ours if we are to fulfill our obligations and responsibilities as professional Industrial Engineers.

The end of World War I brought with it an urgent need for a rapid return to economical manufacture, and a sudden break with the "cost-plus" philosophy. The beginning of professional Industrial Engineering was thus related to the "efficiency expert" era. Here the profession suffered because tightening up is never popular, and many "efficiency experts" were opportunists rather than engineers. The patent medicine prescribed by many of the ill-trained "experts" did not cure the malady, and the failure was charged against truly professional Industrial Engineering.

Just as the medical profession had to wage war upon quackery in medicine, the professional engineer had to wage war upon the charlatans of his day.

During the formative years, Industrial Engineers were generally those who interested themselves in the production phases of a mechanical engineering education. While they were destined to work more with people than were their fellow engineers, a real effort to include applied psychology as an important integral part of their basic education occurred as recently as two decades ago. As a result, we in Industrial Engineering became "tool oriented." We knew much about plant layout, tool design, materials handling, and the production processes of the metalworking industry, in an empirical sense, but very little about the rational theories or fundamental laws upon which the whole American industrial colossus flourished. Further, we were frequently "cook book" specialists. We had recipes; we could "get it done." But while we often undertook to improve industry, our profession—like all others—had a distressing tendency to stagnate in its own methodologies.

Then came the greatest period of urgency our nation has known—World War II. Mathematicians and engineers joined to give us statistical quality control. While the point may still be argued heatedly in some quarters, this "new look" was responsible for demonstrating the usefulness of statistical methods in the probabilistic world of the Industrial Engineer. New light was thrown upon the systems within which we operate, and true engineering analysis in the world of mass production became of age.

Concurrently, the impossibility of waiting for individual geniuses to solve the problems of technological warfare forced the team approach. Operations Research was born and helped us avoid many of the errors in planning made by our enemies. The "Systems Approach" was also conceived.

Change had always been a part of the philosophy of our nation. We, a relatively young country, had always worked on some frontier. But now the *rate* of change bothers us.

So it is in Industrial Engineering. We must continue as practitioners and, at the same time, become creators of new theories and developers of new methods of analysis. We must, therefore, support two main stems of endeavor:

1. Promulgation of the best common current practice.
2. The rational development of scientific laws for industrial operations.

Difficult? Yes. Impossible? No.

How do we accomplish it? We accomplish it through the time-honored practice of using the teamwork of groups of experts, each of whom works on a segment of the overall problem, and has his work coordinated with that of the others.

In the year ahead we must separate contentiousness from intellectual inquiry. We must differentiate between obstinacy and loyalty to a fundamental principle, and we must strive for a new level of mutual understanding between operator and creator, practitioner and researcher, scholar and builder, engineer and scientist.

Industrial Engineering has come of age. Its spectrum now runs from theoretical analysis and abstract thought to empirical practice. The challenge to AIIE to become both the catalyst and the modulator is real. The future has greater potentialities than at any time in our history.

NOTICE

ALL MEMBERS OF THE AIIE AND
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American Institute of Industrial Engineers, Inc.
145 North High Street
Columbus 15, Ohio

INSTITUTE INTERESTS

CALENDAR

September

5–13—Third Annual Intensive Course in Statistical Quality Control; Sever Hall, Washington University, St. Louis, Missouri. Write J. K. Lahr, University College, Washington University.

9–20—A Short Course in Applied Linear Programming; North Carolina State College, Raleigh, North Carolina. Write College Extension Division, N. C. State College, Raleigh, N. C.

23, 24, 25—Sixth Annual Meeting of the Standards Engineers Society—Theme: "Standardization—Economy Through Application"; Hotel Commodore, New York City. Write R. E. Mason, Public Relations Chairman, Room 2624, 70 East 45 Street, New York 17, New York.

24–25—Sixth Annual Industrial Electronics Symposium; Morrison Hotel, Chicago, Illinois. Write H. L. Garbarino (AIEE), Armour Research Foundation, Illinois Institute of Technology, 10 W. 35th St., Chicago 16, Illinois.

January

6, 7 and 8, 1958—The Fourth National Symposium on Reliability and Quality Control; Hotel Statler, Washington, D.C. Write Richard M. Jacobs, RCA Bldg. 108-2, Moorestown, New Jersey.

March

17–21, 1958—Fourth Nuclear Engineering and Science Conference; Chicago, Illinois. Write Atomic Exposition, 117 South 17th Street, Philadelphia 3, Pennsylvania.

CENTRAL ARIZONA CHAPTER

The Central Arizona Chapter began its business meetings with programs intended to familiarize the members with the locale after which the chapter was named, Central Arizona.

Industry is relatively new to Phoenix, Arizona, and the Farmers and Citrus growers are getting to be fewer in number day by day. The industrial development in the past few years has created a need for the Industrial Engineer in Arizona, which can be evidenced by the fact that the Chapter membership is made up of newcomers to Arizona.

In carrying out their program, the officers obtained for speakers, Walter T. Lucking, President of Arizona Public Service Company; Dr. George Boyd, assistant to the President, Arizona State College at Tempe, Arizona; and Lew Haas, Executive Secretary of the Phoenix Chamber of Commerce, who all spoke on the development and growth of Arizona and the Phoenix Metropolitan area.

These introductory meetings were then followed up with programs of a more specific nature. Dr. Herbert R. J. Grosch, Manager, Applications, Computer Department of the General Electric Company in Phoenix spoke on the future of electronics and computers in industry. Mr. M. M. Pentecost, Manager of Factory Accounting for Goodyear Aircraft Corporation in Goodyear, Arizona, spoke on Cost Accounting in Industry. A panel was formed to discuss Industrial Engineering in Arizona and resulted in one of the most satisfying meetings the members had attended, even though the subject was entirely discarded many times throughout the discussion. Another panel is formed for the July meeting with the topic of Preventive Maintenance and Replacement of Machinery and Equipment.

An Education Committee has been formed to produce an Engineering study of our educational system in the secondary schools. The prime function of the committee is to prepare a study of the system as it relates to the colleges and universities in the engineering field. This study will enable the Chapter to make recommendations on the improvement of curriculum for students going on to higher education as well as directing students into the engineering areas.

CLEVELAND CHAPTER

All the members of the Cleveland chapter can feel proud of the highly successful Sixth Annual Spring Conference that our chapter sponsored in March at the Hotel Cleveland. It was a tremendous success. All the plans and preparations for the conference were under the skillful guidance of conference chairman, George Wassel, and he was enthusiastically supported by Bill Ritchie as conference vice-chairman. Quent Groth, as program chairman, John Thompson as arrangements chairman, Joe Terr in charge of programs and publicity, George Calvert exhibits chairman, Ben Pintenich announcements chairman, Al Bloesinger registration chairman, Harry Berlin treasurer, plus assists from Walt Rudolph, Ed Grendel, and Pete Cariota, all contributed to the unusually fine conference. It was reported at the April Chapter meeting that approximately 370 registrants attended the conference here in Cleveland; the largest attendance of any Cleveland Chapter conference. The number of exhibits was unusually high this year, and many were of unusual interest. Many thanks are in order to all the committee chairmen and their staffs for a job well done.

The April meeting of the Cleveland chapter was held April 4th in the Rose Room of Hotel Cleveland. Donald F. Copell discussed work simplification—"To Simplify or Not to Simplify". Mr. Copell is Vice President of the Wagner Baking Corp. of Newark, New Jersey. He has been internationally acclaimed for his distinguished contributions to the industrial engineering field. The lecturer was born and educated in Switzerland. He served as an instructor in methods engineering at Rutgers University, and in 1948 was a recipient of the Gilbreth Medal. He is an expert in setting up and organizing work simplification programs, and is an excellent humorist. Many of his case histories were interspersed with appropriate bits of wit and humor, and the audience had a most pleasant time learning and laughing concurrently. Copell has done considerable reasearch in "work simplification". He stated that today we are on the threshold of a great competitive era in the United States; that to put the "squeeze" on cost requires the efforts of every member of the firm from the custodial staff to the executive board. He further stated that our job as Industrial Engineers is to create proper attitudes toward cost reduction; then to create the proper atmosphere for it through work simplification. It was interesting to note that Mr. Copell feels that price levels have just about reached their present peaks, and that future profits will be realized not necessarily from increased sales, but from reduction of wastes and more efficient operations.

DAYTON CHAPTER

The June meeting of the Dayton chapter took the form of a dinner party for AIIE members, wives and guests when the chapter met on June 22 at Benham Catering in Oakwood. Features of the evening were the most interesting speech by Col. James J. Hausman and the announcement of newly elected officers. Although Col. Hausman now resides in Washington, D.C., he is well known in the Dayton area and has an excellent reputation as a professional speaker. His subject for the evening was "Human Aspects of Engineering." Col. Hausman's engineering background includes his work as an associate professor at Kansas University, where he taught various engineering subjects.

Members and wives of the Great Salt Lake Chapter on tour of the Bingham mine of Kennecott Copper Corp. operations in Utah.

GREAT SALT LAKE CHAPTER

The April meeting of the Great Salt Lake chapter was held at the Bingham mine of the Kennecott Copper Corporation, Utah Copper Division, on Saturday, April 13th. The chapter members and their wives were guests of Kennecott and toured the mine in the "polish car." The tour included a detailed description of the mining operations and some views not generally seen by the visitors to the mine. Scotty Robertson, safety field man, acted as the guide and Dean D. Kerr, assistant general hill foreman, George Deneris, Industrial Engineer, and J. A. Norden, assistant superintendent-maintenance, were in charge of events during the day. V. S. Barlow, General Mine Superintendent, was official company host, and he and Mrs. Barlow entertained our group with a delicious lunch.

HOUSTON CHAPTER

In January 1957 Mr. Dorian Shainin, Industrial Consultant, spoke to a joint meeting of the Houston Chapter AIIE and ASQC on the subject "Breaking Through Industrial Problem Barriers". Mr. Shainin is a speaker of more than ordinary ability and the subject matter of his presentation, the use of statistical analysis techniques in solving industrial problems, exceeded in quality his ability as a speaker. Few of his audience left the meeting without a strong desire to learn more of the techniques demonstrated by Mr. Shainin.

Mr. Eugene Maier, Director of Traffic and Transportation, City of Houston, was the principal speaker at the February Meeting. His subject was "Organization for Industrial Civil Defense". It is doubtful that many of us fully comprehend the fearful magnitude of destruction and chaos we will be subject to in the event of an atomic world war. Mr. Maier told the meeting that in the event of such an attack in the immediate future the principal course of defensive action is evacuation. Properly constructed shelters would be of enormous help and save many lives but there is no bright side in this picture.

At the March meeting, Mr. Vernon Bailey, Director of Port Operations, Port of Houston, presented a program on "Materials Handling at the Port of Houston". This was a joint meeting with the local chapter of the American Materials Handling Society. The members and guests found interesting differences in material handling at a port from material handling in their organizations.

Mr. G. E. Lane, Superintendent Industrial Engineering, Houston Plant, Ethyl Corporation spoke at the April meeting on "A Cost Control Program for a Process Industry". This is a very pertinent subject in the Gulf Coast Area since many of our members are connected with process industries. For those of us who a not, the presentation was a broadening experience and was well received by all who attended the meeting.

In May the Houston Chapter made a Plant Tour of the Napko Paint Company. Before making the tour we attended a very interesting and informative lecture by Mr. J. E. Rench. Napko is a new and very modern plant. This tour provided interesting and useful information on the nature, formulation, manufacture, distribution and use of various paints and related products. Mr. Rench and his associates made at least one point with all who made the tour, "Heed the instructions and recommendations on the container".

In May the Houston Chapter elected the following officers for the 1957–58 year.

President—Bruce Stoughten, University of Houston
Vice President—R. H. Ralston, Champion Paper and Fibre Company
Secretary—J. H. Huffman, Baker Oil Tool Company
Treasurer—J. B. Rogers, Reed Roller Bit Company
Director—C. Mason, Houston Natural Gas Company
Director—J. Tagg, Shell Oil Company

The new officers take office July 1, 1957. Although there are no scheduled summer meetings other than a social meeting, the newly elected officers and the various appointed officers and committees are working on the program and other business for the new year. The 1956–57 year has been a successful year. We ended the year with a 50% increase in membership over the previous year for a total of approximately 100 members, held a successful Work Measurement Conference, had interesting and enlightening programs, established better communications with our members and the general public, improved our organization for handling the chapter business, and are financially solvent.

JAMSHEDPUR, INDIA, CHAPTER

The Eighth Annual Meeting of the Jamshedpur Chapter of AIIE was celebrated at the United Club, December 27, 1956. The President, Mr. V. S. Vernekar, Chief Industrial Engineer, Tata Iron & Steel Co., Ltd., welcomed the guests. The Secretary,

Mr. J. Natarajan, presented the annual report, tracing the growth and activities of the Chapter. Mr. N. J. Lipner, Manager of Industrial & Safety Engineering, Kaiser Engineers' Overseas Corporation, was the chief guest of the function, and he spoke on "Industrial & Safety Engineering in a Construction Company". Mr. Lipner, in his talk, stressed the difference between the problems in production line and construction work and stated that the detailed and repetitive study methods cannot be applied for construction jobs and that day-to-day planning has to be done, especially in the case of a new project. The meeting terminated with a vote of thanks given by Mr. M. S. Katre, Vice-President. All the guests and members present participated in the Annual Day Dinner.

A meeting of the Jamshedpur Chapter of AIIE was held Thursday, May 16, 1957, at the United Club Hall. Prof. Richard F. Bruckart, Professor, Industrial Engineering, Indian Institute of Technology, Kharagpur, Senior Member-at-Large AIIE and former Professor of Industrial Engineering at Texas A. & M., addressed the members on "The Modern Concept of the Industrial Engineer's Work". Prof. Bruckart stressed the importance of keeping pace with new developments and ideas that are taking place in the field of Industrial Engineering such as electronic data processing, operations research, linear programming, ratio delay analysis, etc.

Mr. M. S. Katre, chairman, stated that the Technological Institutes can contribute a lot in this by including the latest developments in their curricula. The meeting was well attended.

LOS ANGELES CHAPTER

The April Meeting was the final event in the highly successful "triple header" prototype that stimulated the interest and increased attendance during the 1956–57 Monthly Dinner affairs. The general meeting was preceded by a Technical Clinic arranged by Chairman Stewart Widoff, and followed by a film of the latest Winter Olympic Games. The featured speakers of the evening, Mr. C. L. Dunsmore, Management Consultant, and Mr. Bernard S. Benson, principal of Benson Lehner Corp., presented educational and thought provoking information relative to "Operations Research and Problem Solving" and "In Search of a Solution—Cerebral Popcorn or Systematic Logic", respectively.

The annual business meeting with installation of new officers was held in May, followed by an evening of informality and socializing by members only. The annual reports indicated the tremendous growth of the local chapter to its present size numbering over 300, the increased interest and attendance at the meetings, and the forward thinking and planning for the 1958 National Convention to be held in Los Angeles. The following members were installed in their respective offices for the 1957–58 year as the President, Arnold A. Cowan, turned over his gavel and received the commendations for the work performed during the past season:

President:	C. Wilson Whitson
1st V.P.:	Donald L. Mihelich
2nd V.P.:	Harry J. Kraig
Secretary:	Walter R. Herbst
Treasurer:	John E. Jardine

Howard Dickason, Chairman of the forthcoming 1958 National Convention, brought the members "up to date" on the planning and the necessity of group participation relative to this special event. The 9th National Annual AIIE Conference and Convention will be held in Los Angeles on June 12, 13, and 14, 1958. Normally, it is held in May of each year, but in our case it was postponed a month in order that members in the mid-west and east could work it into a vacation trip to the west coast. Assisting Mr. Dickason on the Steering Committee are C. Wilson Whitson as co-chairman over Program, Proceedings and Publicity; Peter Pruce as co-chairman over Arrangements, Reception, Registration and Special Events; and Arnold Cowan as Conference Advisor, based on his highly successful administration of the Western Regional Conference held in 1955 at Los Angeles. Harry Kraig, chairman of the Exhibits Committee, has already made arrangements for the space availability and has secured some early pledges that indicate that this area of the Convention will be filled up at an early date and prove to be a worthwhile investment for the advertisers.

Formal dinner meetings during the summer months have been replaced with informal meetings followed by field trips to different types of industries to promote broader understanding of the problems and characteristics of various types of manufacturing facilities. The June Meeting was held at the Southgate, California Plant of General Motors, which assembles the Buicks, Oldsmobiles, and Pontiacs. The July Meeting was held at the Goodyear Tire & Rubber Company in Los Angeles. The August Meeting was held in Van Nuys at the recently completed plant of the Anheuser-Busch Corp., brewers of the famous "Budweiser". Each of these plants typified stages of mechanization and automation peculiar to their own operations and are indicative of the progress of large integrated industries in this direction.

C. L. Cataldi, newly appointed Program Chairman, has lined up a banner array of speakers for the coming season of monthly meetings that started off in high gear with the September affair. The combination of interesting programs and the stimulus of the National Convention are providing a real cohesive force in the continuing growth of this chapter and the promotion of the organizations' ideals in our community.

LOUISVILLE CHAPTER

At our April chapter meeting, Mr. Donald Stohlman, Executive Vice President of the New York office of Serge A. Birn Co., Inc., addressed the members and guests on "Method Time Measurement". Mr. Stohlman said that predetermined measurements are now getting more recognition from a legal standpoint, especially in arbitration cases. Predetermined work measurements are now being accepted by the unions. He went on to say that a new field for work measurement has now filtered into the agricultural phase: for example, in Florida a work measurement tool was used on a one thousand acre farm and a 50 thousand acre ranch. Methods time measurement is now being used internationally. Mr. Stohlman also pointed out that rates set by a work measurement tool will stand against any rate. He illustrated this by speaking of a company in Ohio where grinding rates were set by M.T.M. The men did not meet standard and lost money for six months. When union officials had a rate check, the audit was found to be correct. Now the men are making money.

The May meeting of the Louisville chapter took the form of a plant tour through the Louisville Assembly Plant of Ford Motor Company. Before the actual tour took place, John F. Webster gave a brief resume of the Ford Plant facilities, schedules, manpower, and other general information. Mr. Webster, who is a member of the Louisville AIIE chapter, joined the Ford Motor Company as a Cost Analyst in the Plant Controller's Office in 1953, and is now in the Manufacturing Standards Department.

Arrangements for good speakers and interesting programs must be made well in advance. Ray Robison, outgoing chairman of the Program Committee, and John Rigby, our new chairman (appointed last January to give continuity), have done a commendable job on programs for the coming year. Some of the speakers who are already arranged include Dr. Ben Graham, speaking on "Work Simplification", Dr. William Gomberg, Dr. Irwin Lazarus, Dean R. C. Ernst, and Dr. Marvin Mundel. Dr. Mundel will speak on "Memo Motion Study." Two plant tours also are planned, one of these being the Courier Journal & Louisville Times. Attempts are still being made to secure speakers on the subjects of "Brainstorming" and "Fatigue."

We are proud to present the new officers and committees for the coming year:

President—Marvin Garrett, Hirsch Brothers Co., Inc.
1st. V. Pres.—Thomas Potter, American Radiator & Standard Sanitary Corp.
2nd V. Pres.—Edward Vetter, Peerless Manufacturing Corp.
Treasurer—James Ritchey, Reynolds Metals Co.
Secretary—Janis Pettyjohn, General Electric Co.

MEMPHIS CHAPTER

The regular May meeting was postponed until Wednesday, June 5, at which time the chapter members were taken on a plant tour of Continental Baking Company. The Engineering personnel of the company conducted this most interesting tour of this highly automated plant. This same evening, a thorough report on the progress of the AIIE National Conference was presented by Gene Mariani and Bill King.

The Memphis Chapter held its regular June meeting on Wednesday, June 26, at the Officers Club of Mallory Air Force Base. Our speaker was Mr. E. W. Maxson, whose topic was "The Engineering Problems of the New Proposed Expressway" with special emphasis on the Memphis strip. Mr. Maxson, a graduate of Texas A. & M., is the Principal Assistant to the City Engineer, and has been associated with the city of Memphis since July 1, 1924. He is a member of the Memphis Engineers Club and the American Society of Civil Engineers.

MIDDLE TENNESSEE CHAPTER

At our May meeting, the group toured the plant facilities of General Shoe Corp. in Tullahoma. The tour was conducted by Ed Prather, vice president of our AIIE chapter, and senior plant Industrial Engineer of General Shoe Corp. Following the tour, the AIIE members met at Minor's Restaurant for dinner. After the dinner, the group heard a discussion on the facilities toured. Mr. Prather conducted the discussion. Wendell Graddy, delegate to the National AIIE Convention at New York, then gave a brief report on the convention.

The Middle Tennessee Chapter held its June meeting at the home of Miles J. Maynard. The meeting was planned as an outdoor affair on Mr. Maynard's patio. Members and guests were treated to an old-fashioned barbecue. Following the barbecue, a short business session was conducted by Wendell B. Graddy, president. The latter part of the session was open for membership participation in discussions on chapter policy and agenda for the coming months.

OKLAHOMA CITY CHAPTER

New officers for 1957–58 installed at May meeting of the AIIE Oklahoma City Chapter are, l. to r., E. E. Scott, Treasurer; T. S. Leard, Vice-President; C. O. Hollingshead, President; H. F. Cooper, Secretary.

ROCKY MOUNTAIN CHAPTER

The Rocky Mountain Chapter of the American Institute of Industrial Engineers located in Denver, Colorado, sends its greetings to other chapters throughout these United States and Canada. This being the first time which we have offered any material for publication we shall take the liberty of being a bit more folksy than usual and sort of talk about how we got started.

It was about 4 years ago in 1953 that a small group of Industrial Engineers in Denver got together and decided to found a professional organization. During the first year it was not definitely decided with what national organization the group should become affiliated. The AMA, the SAM among others as well as the AIIE were considered. In spite of the geographical area and lack of large business which are limiting factors for growth and development it was decided that the AIIE would best suit their professional purpose. Many of us feel that the profession still has a long way to go from the "rate cutters" era, and that the national organization is helping to push us rapidly along in the right direction. Our Chapter was thus granted in April, 1954.

Our growth has not been phenomenal but it appears genuine. From a start of approximately twenty members the chapter stood at a total of fifty-four at the beginning of this year. Presently we have sixty-four members. One significant thing is that we are not losing any of the older members. There are also fourteen applications presently submitted to the national organization for acceptance.

Each month, like many of the other chapters, we publish a monthly newsletter. This serves as a combination newsletter and notice of the forthcoming meeting. A copy is not only circulated to each member but to interested non-members as well. Our monthly mailing list is presently one hundred and eighty-four notices.

The attendance for the dinner prior to the meeting has run consistently this year between thirty and forty with attendance at the meeting around sixty. Our program for the year has run as follows:

Sept.—"Industrial Engineering at Glenn L. Martin Company" by Mr. David Levine, Chief Industrial Engineer for G. L. Martin Co.

Oct.—"Story of RAMAC" and "Direct Lines to Decision" were film presentations followed by question and answer periods by Mr. Robert McDonald and Mr. Robert Bruch.

Nov.—Debate: Resolve Automation Benefits Both Management and Labor. This was conducted by our own members Mr. Bill Becker (Technical Services), Mr. Dave Morrell (Gates Rubber Company), Mr. Charles Haney (United Air Lines), Mr. Robert Williams (Colorado University).

Dec.—"The Shape of Things to Come" by Mr. S. A. Johnson, Director of The Denver Research Institute of the University of Denver. Mr. Johnson outlined the value of research in building towards a better community.

Jan.—"The Economics of Capital Investments" by Mr. Edward Campbell, Chief Accountant of Gates Rubber Company. His talk illustrated a practical solution to whether a given machine is economical depending upon the degree of profit desired.

Feb.—"Statistical Tools for Industrial Engineers" by Mr. George E. Bardwell, University of Denver.

Mar.—"System Simulation" by Mr. Warren E. Alberts, Director of Industrial Engineering, United Air Lines.

April—Field trip to the Colorado Fuel and Iron Corporation at Pueblo, Colorado.

May—Business Meeting and election of officers for next year. We also held our installation of officers dinner May 31st. This has become an annual affair to which we invite our wives.

A major project this year was a Cost Control Clinic featuring

Mr. Phil Carroll. This was held on Saturday, April 13th and proved very successful. It was decided to limit the attendance to one hundred and seventy. The final figure turned out to be one hundred and sixty-nine. Mr. Carroll did a commendable job in spite of traveling half the night. The results of his work were well received. We advise any chapter whose treasury is depleted to try Mr. Carroll for size, he puts that extra punkin beside the fodder when the corn's in the shock.

The clinic not only added $1000 to the treasury (over three times what had accumulated from annual dues) but also fourteen applications for membership which are now being processed. It also made a favorable impression upon several business owners and members of management not associated with Industrial Engineering but who are in a position to request their services.

TULSA CHAPTER

At its next to last meeting the Tulsa Chapter was pleased to have the Assistant Chief of Planning, Tulsa Metropolitan Area Planning Commission, Mr. S. W. Griselle, speak on Tulsa's Expressways Program. Mr. Griselle highlighted his talk with historical background of the commission, and discussed generally what programs are underway. The expressway program in Tulsa is one that all engineers, as well as the general public, will be interested in, for its realization will mean safer and better traffic conditions, a greater volume of traffic through Tulsa, and increased industrialization. Its final planning comes at the time when Oklahoma has just completed linking, through Tulsa, the four-lane Turner Turnpike and Will Rogers Turnpike, connecting the Oklahoma State Capitol with Joplin, Missouri.

The last meeting was the annual election of officers and report on the Eighth Conference and Convention. Tulsa Chapter Officers and Directors for the new fiscal year are as follows:

President	Howard G. Childress
Vice President	Lewis B. Roberts
Secretary	John W. Hawkins
Treasurer	Harold Colvard
Directors	Edward L. Cunningham
	Robert O. Greaves
	Carl A. Stevens
	Edgar K. Van Eman, Jr.

Each year the Tulsa Chapter presents an award to the outstanding graduating senior in the school of Industrial Engineering and Management, Oklahoma Institute of Technology, at Oklahoma State University. Basis of selection is scholastic achievement, personal qualities, leadership and service in student chapter of AIIE, and campus activities. This year's achievement and leadership award was presented to Mr. William Pitts who compiled an outstanding record while at O.I.T. The presentation was made by retiring President Robert O. Greaves at the last meeting of the fiscal year. The award includes a certificate describing the honor, a year's paid membership in AIIE, and an AIIE lapel pin. In addition, the recipient's name is inscribed on a wall plaque, previously presented to O.I.T. Mr. Pitts is presently employed in Oklahoma City.

BOARD OF TRUSTEES' MEETING

Buffalo Room, Hotel Statler
New York City, New York
May 17, 1957

The Board of Trustees of AIIE is the official governing body of your organization. This group meets to conduct business for you twice a year. The official minutes of the May Board of Trustees' meeting are published in the Journal to keep you informed of AIIE activity.

President Emerson called the meeting to order at 9:45 A. M. Among those attending were:

Howard P. Emerson, President
Floyd J. Titler, First Vice President
Joseph L. Southern, Executive Secretary
Stephen D. Veirs, Treasurer
Frank T. Geyer, Assistant Executive Secretary
Irwin P. Lazarus, Vice President, Midwestern Region
John M. MacBrayne, Vice President, Southeastern Region
Ralph W. Updegraff, Vice President, Central Region
Wilson J. Bentley, Vice President, Southwestern Region
James D. Nordahl, Vice President, Western Region
Edwin L. Slagle, Past President
Donald G. Malcolm, Past President
Frank F. Groseclose, Board Member-at-Large
S. Kyle Reed, Board Member-at-Large

And:

Gordon B. Carson, President Elect
George F. Gustat, Director, Public Relations
Harry L. Davis, Chairman, AIIE Film Committee
Vernon D. Foster, Director, National Meetings
Alex W. Rathe, Chairman, Professional Relations Committee
Frank J. Johnson, Representative, Atlanta
Clinton A. Jaycox, Representative, Detroit
Robert Kantor, Representative, Detroit
Ross Hammond, Representative, Dallas-Ft. Worth
Dave A. Overton, Chairman, Membership Qualifications Committee
Arthur L. Chilman, Vice President Elect, Western Region
James T. French, Vice President Elect, Southeastern Region
M. A. Payne, Director, Chapter Expansion
Andrew Schultz, Jr., Director, Research
Charles Brennan, Director, Student Chapters
Howard M. Dickason, General Co-Chairman, 1958 Conference
Robert N. Lehner, Editor-in-Chief, Journal
Robert M. Eastman Chairman, Publications Coordination and Plans
Don A. Trenwith, Business Administrator

1. *Minutes of October 13, 1956, Board of Trustees Meeting*—The minutes of the October 13, 1956, Board of Trustees Meeting were approved as presented.

OLD BUSINESS

2a. *Government Operations*—The board discussed the written report presented by the Chairman of the Government Operations Committee, Mr. Frank T. Geyer. Mr. Veirs moved that the report be published in the *Journal of Industrial Engineering* as a committee report. Seconded by Mr. MacBrayne. Motion carried.

2b. *Request from University of Puerto Rico*—President Emerson reviewed the past action of the executive committee in refusing to waive the ECPD accreditation requirement which prevents the chartering of a Student Chapter at the University of Puerto Rico. He requested reconsideration by the Board of Trustees. The Board reviewed the AIIE Constitution as it applies to this problem and the waivers granted by other engineering societies to the students of this university. Colonel Groseclose moved that the ECPD accreditation requirement be waived and charter be granted the University of Puerto Rico, Student Group. Seconded by Mr. Veirs. The motion was unanimously defeated.

2c. *Other Old Business*

2c1. *Recognition of Industrial Engineers who have become Deans of Engineering Colleges*—Mr. Bentley listed the following Industrial Engineers who have advanced to the position of Dean, or Assistant Dean, of Engineering Colleges:

Gordon B. Carson, Dean of Engineering, Ohio State University
Robert H. Roy, Dean of Engineering, Johns Hopkins University
M. R. Lohmann, Dean of Engineering, Oklahoma A. & M. College
Robert J. Parden, Dean of Engineering, Santa Clara University

Rocker T. Staton, Jr., Ass't Dean of Engineering, Georgia Tech.

Robert G. Carson, Jr., Ass't Dean of Engineering, North Carolina State College

Mr. Bentley moved that the Board go on record as recognizing the achievements of these Industrial Engineers. Seconded by Mr. Southern. Motion passed unanimously.

NEW BUSINESS

3a. *Membership Report*—Mr. Southern presented the May 1, 1957, membership report and amended the figures for the benefit of the Board, to May 14, 1957. Mr. Geyer moved the report be accepted. Seconded by Mr. Titler. Motion passed.

3b. *Financial Report*—Mr. Veirs reported on the financial condition of the American Institute of Industrial Engineers and presented the financial report for the year ending April 30, 1957. This report included a semi-annual review of the budget. Mr. Veirs showed the slides that had been prepared for use on the convention floor on the following day. Colonel Groseclose moved that the Board receive this report and approve the expense budget as a guide, subject to revision by the Board of Trustees, and that Mr. Veirs be commended for the excellence of the financial report. Mr. Nordahl seconded the motion. The motion was unanimously passed.

3c. *Semi-Annual Review of the Budget*—The Board then discussed further the guide Mr. Veirs had presented and which had been approved by the Board so that those responsible for the preparation of the coming fiscal year's budget would have some indication of the desires of the Board in the manner of allocation of funds.

3d. *Executive Secretary Appointment*—President Emerson made the presentation of this item in the absence of Mr. Payne. President Emerson reported that a mail vote of the Board of Trustees had provided the appointment of Floyd J. Titler as the first full time paid Executive Secretary of the organization, Mr. Titler to begin work on February 1, 1958. President Emerson asked for a confirmation of this action. Mr. Nordahl moved that the Board go on record as confirming the mail vote. The motion was seconded by Mr. MacBrayne. During the discussion it was pointed out the original choice was unanimous by the Research Committee that made the selection; by the Executive Committee; and by the Board of Trustees. The motion was voted upon and unanimously passed.

Mr. Reed moved that since Joe Southern has agreed to serve as unpaid secretary until Mr. Titler's term begins, that he be reappointed in that position for the interim period. The motion was seconded by Mr. Geyer. The motion was voted upon and unanimously passed.

President Emerson reported that the Executive Committee would like to recommend, in appreciation of the services of Joe Southern, that he be awarded Life Status or Life Membership in the AIIE. The Executive Committee recommends this as an appropriate form of recognition and believes it is in order for this Board to either approve that suggestion or make some other suggestion. Mr. Nordahl moved that the recommendation of the Executive Committee be approved. Mr. MacBrayne seconded the motion. The motion was passed by acclamation. When Mr. Titler and Mr. Southern returned to the room, the President told the two gentlemen of the action that had taken place during their absence. Mr. Titler thanked him for the appointment. President Emerson then announced to Joe Southern the action of the activity in his behalf, "This action brings up a change of status for Joe Southern. This Board of Trustees since 1952 has relied upon Joe's judgment and recommendations. It hasn't always taken these recommendations. Whenever the Board turned them down, however, Executive Secretary Joe has carried out the will of the Board with great objectivity. Before we had a paid Business Administrator, our Executive Secretary bore the brunt of the work and it must have been terrific.

"In recognition of the time, energy and worry that has been his (we would like also to have this recognition of his family and their part in the whole thing), and, again on the recommendation of the Executive Committee and unanimous action of the Board of Trustees, as a form of recognition for his service, we would like to award you, Brother Joe, a Life Status in the American Institute of Industrial Engineers." Mr. Southern's reply: "I am supposed to sign these things. I have been doublecrossed. There isn't anything I can say fellows except just thanks. I certainly don't feel that I have done anything unique or unusual. It has been my pleasure to have been able to serve and work with the people that we have to work with. This makes it just 100% beyond anything I ever expected—the satisfaction of the job to be. Thanks a lot." (Applause)

3e. *Board Member-at-Large*—The Board voted on the replacement for the Board Member-at-Large position resigned by Mr. Titler in light of his new appointment as paid Executive Secretary and his election as First Vice President. Announcement of Board action is deferred until the man selected has had a chance to accept or refuse the appointment.

3f. *Constitution and By-Laws Changes*—Mr. Titler distributed copies of proposed changes in the Constitution and By-Laws of the AIIE. Mr. Titler moved that the proposed changes be approved by the Board and passed on to the membership for vote. Seconded by Mr. Southern. The motion was voted upon and unanimously passed. Mr. Titler read in detail the proposed changes in the By-Laws. The proposed changes were discussed by the Board members. Mr. Titler moved that these recommended changes be made. Motion was seconded by Mr. Slagle. The motion was voted upon and unanimously passed. (Copies of the By-Laws and Constitution changes are appended to these minutes.)

Mr. Titler discussed the problem of representatives to the EJC as appointed by the American Institute of Industrial Engineers. He pointed out that the representative must be a member of the Board of Trustees of the AIIE. Two possibilities exist. One is to hold the appointment to a member of the Board of Trustees. The alternative is to make a provision in the Constitution that anybody appointed by the President to the EJC Board would automatically become a member of the Board of Trustees. As a compromise proposal, Mr. Titler made the following suggestion—add a new section to the Constitution to read as follows:

"The President with the approval of the Board of Trustees shall appoint a regular member, other than an associate member, as the representative of the American Institute of Industrial Engineers to the Board of the Engineers Joint Council. Such appointee shall, at the time of his appointment, be a member of the AIIE Board of Trustees or, if he is not such a Board member, shall by the fact of his appointment become for the term of his appointment to the Board of EJC, a Board Member-at-Large and thereby a member of the Board of Trustees of the American Institute of Industrial Engineers. The President with the approval of the Board of Trustees shall appoint also an alternate to attend meetings of the EJC Board."

3f1. *Report of the Chairman of the Membership Qualifications Committee*—Mr. Titler moved that the Membership Qualifications Committee be commended for the excellent and voluminous amount of work it has carried on during the past year. Motion seconded by Mr. Slagle. The motion was voted upon and unanimously passed.

President Emerson announced that the meeting would be adjourned until 1:30. The meeting was re-convened at 2:30.

3g. *Location of the 1959 Convention*—President Emerson turned the chair over to Mr. Vernon D. Foster, Director of Conventions. Mr. Foster announced that he had three bids for the 1959 Convention—they were Atlanta, Dallas and Detroit. Each of the

representatives of the bidding chapters was given an opportunity to speak on behalf of his city: speaking for Atlanta, Mr. Frank Johnson; speaking for Dallas, Mr. Ross Hammond; and speaking for Detroit, Mr. Clinton A. Jaycox. President Emerson provided an opportunity for the Regional Vice Presidents involved to speak in behalf of their groups. Mr. MacBrayne spoke for Atlanta, Mr. Bentley for Dallas, and Mr. Updegraff for Detroit.

After considerable discussion about conventions, past convention sites, hotel accommodations, etc., the Board moved on to action in this matter. President Emerson called for a vote on the meeting. He appointed Mr. Southern, Mr. Trenwith, and Mr. Foster to count the ballots. Mr. Southern declined since he would be voting. A secret ballot was taken of the Board. Mr. Foster, as Director of National Meetings, announced the results—Atlanta was the winner.

3h. *Relationships with Other Organizations*—President Emerson reported on his previous correspondence with the representatives of Alpha Pi Mu. These concern the use of the *Cogwheel* as a publication of Alpha Pi Mu in cooperation with the *Journal of Industrial Engineering* as a publication of the AIIE. Robert Eastman, as Chairman of the Publications Coordination Committee was asked to make recommendations.

After listening to Dr. Eastman's report and considering all the aspects of the cooperative venture, the Board instructed the President to go ahead with whatever cooperative relationships might be established at this time under existing regulations.

President Emerson asked Mr. Malcolm to report on relationships with TIMS.

Mr. Malcolm moved that we continue our cooperation with the Operations Research Society and the Institute for Management Science in the area of staging joint symposia on Systems Simulation, that other meetings where there is mutual interest be encouraged, and that the form of sponsorship should be such that it is equal participation and that AIIE have equal representation in the planning and promulgation of the program. Colonel Groseclose seconded the motion. After considerable discussion, the motion was voted upon and passed. Mr. Geyer voting "no".

3i. *Public Relations*—Mr. Harry L. Davis, representing the Rochester Chapter and Chairman of the Movie Committee made a lengthy report. Mr. Davis' report covered the cost of making the movie, the methods, the script, and the means of distribution. His report covered the possibilities of financing the making of the film. Colonel Groseclose moved that the Board authorize the Rochester Chapter to proceed with this matter of endeavoring to produce a film, with authority to approach corporations or foundations or any other organization that seems appropriate and the various chapters of AIIE. Mr. Updegraff seconded the motion. The motion was voted upon and unanimously passed.

3il. President Emerson reported on the action of the Executive Committee in withholding action on the proposed letters to executives of various corporations. The proposal is to send letters over the President's signature to a group of selected executives calling attention to interesting technical articles, probably in the *Journal*, but also perhaps other publications. The letters for use had been prepared by George Gustat. Mr. Southern moved that we go ahead and try out some of these letters. The motion was seconded by Mr. Slagle. The motion was voted upon and unanimously passed.

3j. *Participation in United Engineering Trustees Building, New York City*—President Emerson called on Mr. Southern and Colonel Groseclose to discuss this problem. Mr. Southern summarized the outlook of the National Headquarters toward the proposed move to New York City. Colonel Groseclose, as chairman of a committee to investigate the problem, made the following report:

"We have no inclination of what our requirements are going to be. We do not know what the cost of moving is going to be. We do not know what obligations we will automatically assume by getting in the Big League. It is true more people come into New York than Columbus, Ohio, in the normal course of events, and I think it would be a considerable advantage to be here for that reason. Furthermore, this closer communication that we would get seems quite logical. On the other hand, I have talked to a number of people in the various societies, and they say there is very little visiting; that they still do most of their correspondence by mail. We also need to know who else is going to come in on this deal and who else will be involved in it, and a lot of other questions we have already discussed."

Dr. Rathe, as Chairman of the Professional Relations Committee, was asked to make his comments. After considerable discussion of Dr. Rathe's report and recommendation, the Board moved on to act. Colonel Groseclose moved that a study be continued under the direction of Matthew Payne with a target date of a report to be made to the fall Board Meeting. Mr. Slagle seconded the motion. The motion was voted upon and unanimously passed.

3k. *Fellow Awards*—Irwin P. Lazarus, Vice President of the Midwestern Region, recommended Dr. Lawrence W. Wallace be approved as a Fellow of the AIIE. Vice President Lazarus gave a detailed account of Dr. Wallace's history. Mr. Slagle moved that Dr. Wallace be approved as a Fellow of the AIIE. Mr. Malcolm seconded the motion. The motion was voted upon and unanimously passed.

3l. *Other New Business*

3l-1. *Research Committees*—Dr. Andrew Schultz gave a lengthy discussion of the year's activities of the Research Committees and their recent meetings here in the hotel. He discussed the Prize Committee; that it is their idea to grant four prizes at the Annual Convention, and suggested it might involve traveling expenses. He discussed the budget, the carrying on of symposia, how they would be handled and financed. He discussed the publication of articles. The Board thanked Dr. Schultz for his report.

3l-2. *Length of Office, 1957–1958 Board of Trustees*—The Board discussed this problem arising for the first time in the history of the organization. The incoming Board of Trustees will not be replaced as is normal practice until June of 1958 due to change of convention date. This means that this Board will be in effect for 13 months instead of the usual 12. Mr. Southern moved that the Board take cognizance of this fact and approve the incoming Board's continuation for 13 months. Mr. MacBrayne seconded the motion. The motion was unanimously passed.

3l-3. *Invitation from the Chinese Institute of Engineers*—After reading the invitation from the Chinese Institute of Engineers to have one of our Board Members attend their Convention on Saturday, June 15th in New York City, Mr. Southern made the following motion:

"That President Emerson request Norman Barish, as our Director of International Relations, accept the invitation and attend this meeting." The motion was seconded by Mr. MacBrayne. The motion was voted upon and unanimously passed.

3l-4. *Adjournment*—There being no further business, the meeting was adjourned at 5:45 p. m.

Next Meeting of the Board of Trustees—The time and place of the next Board of Trustees meeting will be announced by President Elect Gordon B. Carson. (September 28, 1957)

PROPOSED AMENDMENTS TO THE AIIE CONSTITUTION AND BY-LAWS, MAY 16, 1957

Constitution

Article VII, Section 8:

Now reads:

"The National Officers of the AIIE shall be as follows: President, First Vice President, Executive Secretary, Assist-

ant Executive Secretary, Treasurer, three Board Members-at-Large, and one Vice President from each Region."

Would read:

"The National Officers of the AIIE shall be as follows: President, First Vice President, Executive Secretary, Treasurer, three Board Members-at-Large, and one Vice President from each Region."

Article VII, Section 12 (First Sentence):

Now reads:

"A slate of officers, excluding the Regional Vice Presidents, Executive Secretary, and the Assistant Executive Secretary, shall be drawn up yearly by a nominating committee consisting of the immediate past three Presidents and the current President."

Would read:

"A slate of officers excluding the Regional Vice Presidents and the Executive Secretary shall be drawn up yearly by a nominating committee consisting of the immediate past three Presidents and the current President."

Article VII, Section 14:

Now reads:

"The positions of Executive Secretary and Assistant Executive Secretary shall be filled by appointment by the Board of Trustees."

Would read:

"The office of Executive Secretary shall be filled by appointment by the Board of Trustees."

Article VII, Section 15 (First Sentence):

Now reads:

"The President, First Vice President, Executive Secretary, Assistant Executive Secretary, Treasurer, and retiring President shall constitute the Executive Committee, and shall have the duties and powers delegated to it by the Board of Trustees."

Would read:

"The President, First Vice President, Executive Secretary, Treasurer and the immediate past President shall constitute the Executive Committee, and shall have the duties and powers delegated to it by the Board of Trustees."

Article VII, Section 20:

Now reads:

"The Assistant Executive Secretary shall assist the Executive Secretary and have additional duties as may be delegated to him by the Board of Trustees."

Would be eliminated in its entirety.

By-Laws

Article II, Section 1:

Now reads:

"Standing committees of the AIIE shall be an Executive Committee and Qualifications Committee, both as defined in the Constitution; Professional Practices Committee and an Education Committee. All standing committees shall be appointed by the President and shall perform such duties as may be assigned by him."

Would read:

"Planning and Policy Committees shall be: Professional Relations, Organization, Finance, Long Range Planning, Special Surveys, and Publications Coordination. The chairmen of these committees shall be appointed by the President and shall perform such duties as he may assign. The Editor of the *Journal of Industrial Engineering* shall be appointed by the President and the Board of Trustees."

Article III:

Now reads:

"Each Vice President shall check the activities of the Chapters in his region and present an annual report to the Executive Secretary. In addition, he shall arrange for a Regional Conference and he shall encourage a large turn-out of the members-at-large. He shall present a brief written report on his region to the National Convention."

Would read:

"Each Regional Vice President shall keep in close contact with the Chapters and members-at-large in his region, encouraging and advising them in their activities. He shall assist in arranging for Regional Conferences. He shall prepare an annual report of regional activities for the First Vice President and deliver a brief report at the Annual Convention."

Article VI, Section 2 (Last Sentence):

Now reads:

"Each Chapter President shall prepare a report for presentation to the National Convention."

Would read:

"Prior to the National Convention, each Chapter President shall prepare and submit to his Regional Vice President a written report on his chapter activities for the year."

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RECENT READABLES

GENERAL

"A Short Cut Graphic Method for Fitting the Best Straight Line to a Series of Points", by S. I. Askovitz, *Journal of the American Statistical Association*, page 13, March 1957.

A simple technique is presented for obtaining without calculation the best fitting line according to the least criterion, provided the points are equally spaced horizontally. A graphic measure of residual variability is also derived.

"Economic Receiving and Distributing Points as Found by the Median Method", by W. J. Merrill and W. H. Hoffman, *Advanced Management*, page 19, May 1957.

There are many situations where a business establishment would be benefited by finding a central location which would minimize cost or distance traveled. Some typical situations are location of: (1) shipping or receiving points, (2) department layout, (3) tool-room location, and such—right down to the level of locating drinking fountains.

In this paper, a method is presented which differs basically from the method now in use for problems of this type. Necessarily, any reasonably rapid mathematical method applied to actual operations gives, at best, an approximate answer. This method, the author claims, merely gives better approximations than before. The example and discussion are in terms of shipping point location but can be applied to other problems where minimum distance is required.

"Problems of Maintaining and Replacing Modern Office Equipment", by D. L. Gibson, *Office Executive*, June 1957.

With the increased use and complexity of office equipment, machine maintenance and replacement problems have moved into the office. No longer can the average company repairman take every office machine repair job in his stride. Specialized training is essential.

Dependence on distributors and manufacturers may sometimes result in more down time than is desirable. Two principal methods of obtaining maintenance service from outside agencies, such as manufacturers' and distributors' repair departments or independent repair shops, are the maintenance contract plan and the service call plan. These are explained.

To derive the utmost benefits from maintenance expenditures, planning and control functions should be handled on a centralized basis. All requests for maintenance should be channeled through one office or person for review and approval.

"Man Machine Systems", by R. Coburn, *Machine Design*, May 16, 1957.

Design of manual controls and visual indicators strongly influences degree of coordination between a machine and its operator. Here are seven rules for designing most effective arrangements:

1. Make displays and controls compatible.
2. Use functional grouping.
3. Employ sequential arrangements.
4. Arrange elements according to importance and frequency of use.
5. Align indexes of check reading dials.
6. Use symmetry sparingly.
7. Stratify displays and controls according to function.

"How to Tackle Problems", by F. A. Magoun, *Modern Materials Handling*, page 83, May 1957.

Modern executives endeavor to systematize the processes in their plants to insure a product of standard excellence. In this they have succeeded remarkably well. But most of an executive's time is taken up with the occasional problem, the unusual circumstance, the exceptional situation.

Remembering that no method is any better than the man who uses it, the author proposes a procedure which will reasonably ensure a correct answer in any situation.

His method for tackling problems is:

1. PREPARE
   a. Discover and eliminate bias.
   b. List the points of view from which the problem must be examined.
   c. Gather significant facts.
   d. Write out a statement of the fundamental problem.
2. ANALYZE
   a. See the problem as a whole.
   b. Find the key factor in a problem.
   c. Devise a total solution.
3. ACT
   a. Adapt your action to the circumstances.
   b. Maintain an open minded judicial attitude.
   c. Proceed one step at a time.
4. EVALUATE THE RESULTS
5. MAINTAIN OR FOLLOW UP TO ENSURE STANDARD PERFORMANCE

LINEAR PROGRAMMING

"Applying Linear Programming to Inventory Planning in a Seasonal Market", by D. W. Moffett, *Transactions of the ASME*, page 809, May 1957.

Cyclic variations of demand occur in many industries and for many reasons. A great deal of study and research work has been done to try to predict seasonal-market fluctuations so that manufacturers of goods might plan their production accordingly. These efforts have met with considerable success.

Cyclic variations are not limited to items produced for a seasonal market, however. In some plants, the demand for parts for an assembly may be cyclically variable because the assembly is produced only in certain seasons. In the automobile industry, for example, the annual model change causes a slump in the demand for parts similar to a seasonal-market variation.

This paper describes an application of linear programming to the problem of providing stable levels of employment in a plant producing parts for an assembly line which operates at a seasonally variable rate. Linear programming makes it possible to formulate a plan for maintaining stable production levels with minimum cost.

MATERIALS HANDLING

"Streamlined Shipping Operations", by D. J. Lasiter, *Modern Materials Handling*, page 88, May 1957.

Designating the location of the customer (and hence the carrier to be used) before a product is packaged—together with automatic sorting of packaged products—makes it possible to eliminate the manual handling required in moving packages to the proper carrier. It also cuts the floor space required in the packaging and shipping area, as there is no need for floor storage.

Electric typewriters at IBM's Kingston, N. Y. plant now move directly and automatically from the production area to one of many carriers being loaded for shipment to customers.

Before packaging begins, orders from customers are checked for quantities and types of electric typewriters. Each individual requirement is met by removing the desired typewriter from an overhead conveyor which "circles" the packaging station loaded with different types and styles of typewriters.

After packaging, the key step is performed: a reflective tape is positioned on the carton according to the destination indicated on the shipping label. Height of the reflective tape from the bottom of the carton determines which electric eye will later act to send the carton down a roller conveyor into one of the carriers. A preprinted scale on the carton aids in positioning the tape.

A reflection system is used to activate the sorting system rather than other methods, because it was found to be the most practical method of selecting cases that are of the same size.

"Seven Steps to Lower Handling Costs", by J. R. Arwood, *Modern Materials Handling*, page 104, May 1957.

Probably the most successful cost-cutting techniques for general application are these:

1. Evaluate all areas where costs are attributable to materials handling.
2. Analyze the flow of materials.
3. Analyze the layout of your plant.
4. Integrate the materials handling function into the organization.
5. Analyze materials handling and packaging methods.
6. Train materials handling and packaging personnel.
7. Evaluate, select, and utilize equipment properly.

Only these seven have been identified for discussion. These can be subdivided or combined to suit particular circumstances and the preference of any particular analyst. Basically, however, they cover the major areas for cost reduction in materials handling.

WORK MEASUREMENT

"Now—Predetermined Times for Materials Handling", by E. J. Dronzer, *Modern Materials Handling*, page 97, July 1957.

The author proposes the use of predetermined time standards to positively evaluate alternate proposed handling methods. The use of these standards will permit the user to:

1. Predetermine with exactness the most economical and effective materials handling methods and devices to use under a given set of conditions.
2. Scientifically predetermine the most economical plant layout, and all necessary related details affected by materials handling techniques and equipment.
3. Accurately predetermine the advantages of modernizing, repairing and/or replacing existing materials handling equipment.
4. Establish consistent and accurate time standards for incentive wage payment or for measured day work performance—without the necessity for taking long, irritating, and expensive time studies.
5. Balance operations and equipment scheduling through scientific time predetermination.
6. Improve customer service through speedier and safer delivery methods.
7. Design materials handling equipment for high levels of safety as well as economy of use.
8. Predetermine the most effective materials handling devices to avoid costly and uneconomical purchases.

BOOKS

Analog Computer Techniques, by Clarence L. Johnson, U. S. Air Force Institute of Technology, 264 pages, 6 x 9 in. clothbound, published by McGraw Hill Book Co., Inc., 330 West 42nd St., New York 36, N. Y.

Designed as an aid to those learning to use electronic analog computers (or electronic differential analyzers), this book makes becoming an experienced computer operator easier for the engineer. Following the introductory and general material on electronic analog computation, the volume gives specific techniques for the solution of difficult or unusual problems. The book treats in detail the use of diodes and differential relays in analog computation. Emphasis is given to function generating techniques, including methods of representing functions of more than one variable.

Statistical Methods in Quality Control, by Dudley J. Cowden, Prentice-Hall, Inc., New York, 1956. Cloth, 6 x 9 in., 751 pages, price $12.

The first twelve chapters of this book deal mainly with statistical methods in quality control and explain the relationships between probability, statistics and quality control. Other chapters deal with process and product control; use of control charts for variables during production; comparison of process control plans; economics of control charts; and single, double and multiple sequential sampling plans.

Industrial Wage and Salary Control, by R. W. Gilmour, New York, John Wiley & Sons, Inc., 1956, 261 pages, price $7.50.

Job evaluation is a technique designed to relate systematically the "inherent" worth of jobs (measured in non-monetary dimensions) with their money rates. Its use is predicated upon the belief that the labor market functions imperfectly and hence (1) that wage-rate inequities are created which cause employee unrest and (2) that wage-rate uncertainties develop which preclude effective wage and salary control. Its use has expanded significantly in the past fifteen years, in part because it was a mechanism by means of which employees and unions were able to secure wage gains otherwise denied by the wage and salary controls of World War II, and in larger measure because of a belief that it afforded a logical means for wage rationalization.

This book explores one such method; it is "a practical presentation of the development, installation and administration of point evaluation plans as the basis for sound wage and salary controls."

Work Sampling, by R. E. Heiland & W. J. Richardson, McGraw-Hill Book Co., 243 pages, $6.00.

A thorough "how-to" presentation of the concepts and practices of Work Sampling, including basic theory and applications.

Introduction to Data Processing, by Haskin & Sells, New York, 1957, 107 pages, free.

An excellent survey of data processing concepts, from basic data processing operations, through electronic data processing and integrated data processing.

Systems Engineering—An Introduction to the Design of Large-scale Systems, by H. N. Goode and R. E. Machol, McGraw-Hill Book Co., N. Y., 1957, 551 pages, $10.00.

This book shows how a number of very important fields such as statistics, computers, game theory, servomechanisms and control are put together by a group of systems engineers, e.g. the development of radar systems, telephone systems, or guided missile systems. It is an excellent presentation, with generous use of mathematical analysis.

Linear Programming, by D. U. Greenwald, The Ronald Press Company, New York, 1957, 75 pages, $3.00.

A concise treatment of the simplex method of linear programming prepared primarily for the engineer and manager. The author has concentrated on the simplex technique, as it is used in hand-computed solutions of typical engineering, finance and management problems.

I. E. OPPORTUNITIES

WHAT IT IS

The industrial engineering opportunities service is a functional committee of the American Institute of Industrial Engineers which collects information concerning employment opportunities on a nationwide basis and provides this information to members upon request. The committee is composed of members from the Columbus, Ohio chapter and the information is furnished free as a service to industry and Industrial Engineers.

SERVICES PROVIDED

Some of the known job openings will be published in condensed form in each issue of the Journal of Industrial Engineering which is issued bi-monthly to over 6,000 members and student members of the AIIE.

In addition, a monthly I. E. Opportunities Bulletin is supplied to over seventy chapters located throughout the United States.

Each job opening is assigned a "P" number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

ADDRESS OF THE SERVICE

I. E. Opportunities Service
American Institute of Industrial Engineers
145 North High Street
Columbus 15, Ohio

EMPLOYERS

Employers having openings for qualified Industrial Engineers are invited to list them with the Industrial Engineering Opportunities Service. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service. By publicizing your job openings with our Institute, you are sure of reaching high calibre men who have passed the Institute's strict membership qualifications and are fully qualified to fill many types of Industrial Engineering jobs.

Industrial Engineers are often employed in such fields as Work Measurement, Production Control, Plant Engineering, Operations Research, Industrial Relations, Sales, and Management. For a more complete coverage, see the following list of job classifications. Please do not hesitate to forward information on jobs in any area where it is recognized that an Industrial Engineering background will be of value.

To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the above address: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

This information will be publicized to the members in condensed form in the Journal and in monthly chapter Bulletins. Company names are not shown. Should you desire a large ad elsewhere in the Journal advertising rates will be quoted upon request.

MEMBERS SEEKING JOB OPPORTUNITIES

The following list shows job openings available on Aug. 1, 1957. If you would like more information about one or more of the positions listed, mail the "P" numbers with your name and address to the Opportunities Service at the above address. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening so you must take the initiative yourself.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
1	Consult.	Ill	×	Broad			7–10	31	38
2	Education	Ga		51, 52, 31, 47		Ph.D.			
3	Prec. Mach. Shop	NY		94	10–12			35	45
6	Warehouse	NJ		94					
11	Airline	NY		70, 42, 43			5–10		
12	Steel Bldg. Mfg.	Ind							
13	Electronic Mfg.	Ind		11, 13, 19	5–10		2–15		
14	Aluminum	W Va		Sr. I.E.				25	35
15	Tech Magazine, Ed	Mass	×	43			Editor		
16	Airline	Cal		31, 43, 11					
17	Air Force	O		11, 13, 42, 31, 38	7.5–9		4–5		
19	Navy	Fla		30, 41, 42	6.1				
20	Electric, Mfg.	Mo							
21	Education	Mass							
22	Education	Cal		10					
23	Education	NY		10, 30, 40, 52					
24	Education	O		10, 20, 30, 42, 66	4.5–6.0				

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
25	Education	Wis							
26	Education	NC			4.2–4.8	M.S.			
27	Education	Puerto Rico		37, 53, 31					
28	Education	Va							
29	Garment Mfg.	Northeast		37, 31					
31	Paper Mill	Wis		11, 45, 80, 70, 32			1–5		30
32	Rubber Products	O		40					
34	Mgmt. Consult.	O	×	40			P.E.		
35	Consult. Client	O		91—(31)	12–14			35	
38	Metal Min & Proc.	S A		92—(10, 20, 60)	12 + B		10	35	45
39	Education	Neb							
41	Mgmt. Consult	O	×	10, 21, 31			5–7		
42	Hospital	O		10	4.8–7.2				
43	Airline	Cal	×	11, 13	6–7.2				
44	Chemical Proc.	W Va		10, 42, 43, 72			1–3		
45	Steel Products	O		11, 13	4.8–5.4		0–2		
47	Chemical Proc.	Conn		22, 23, 42, 43			3–8		
48	Chemical Proc.	NY		22, 23					
49	Graphic Arts	Ill		11, 20, 42, 43, 70			3–5	25	35
54	Hyd. Press Mfg.	O		11, 13, 42	5.4–6.6				
55	Post Office	Kas	×	11, 13, 42, 49	8.5–10.8				
58	Navy	Pa		10					
65	Machine Tool	Wis		11, 13					
67	Army Ordnance	Pa			6.1–7.6				
68	Education	Pa		10, 20, 31, 42					
69	Steel Products	W Va		26					
70	Education	NY		50		Ph.D.			
71	Mgmt. Consult.	Ill	×	13, 21, 38, 42, 47, 70					
72	Airline	Ill		70, 42, 43					
73	Consultant	Pa	×	13, 21					
75	Army Ord.	Ill		13, 31, 37, 70	7–9		2–4		
76	Trans.	Panama		48	9.5–				
77	Post Office	Minn		92—38, 40, 13	7.7–8.5		4		
78	Mining & Smelt.	NM		91—(10, 20, 30, 40)	8–11.1				45
79	Mining & Smelt.	NM		10, 20, 30, 40			6–9.4		45
80	Metal Prod.	Midwest		95—30, 13	12 + B		15	35	45
81	Household Prod.	O		70, 38, 50, 11	+ R		0–5		
83	Textile Co.	Ga		37, 42, 38	4.8–7.5				30
84	Education	NY		50 or 60	5.0–9.0				
85	Aircraft Eng.	NJ		10 or 50					
86	Public Utility	DC		13, 18, 37, 50, 52					
87	Linoleum Mfg.	Pa		42, 26, 11, 53, 81			0–3		
88	Air Force	O		13					
89	Foundry	Cal							
90	Education	Fla							
91	Syn. Fibers & Films	Pa, Va, W Va		10, 20, 42, 43, 72			0–5		
92	Paper Mill	Pa		11, 13, 42			2–3		
93	Foundry	Ill		11, 19, 30					
95	Airframe Mfg.	Midwest		92—13, 19, 11, 40			5	30	40
96	Navy	Md		40	7.5–8.6		3.5		
97	Railroad	Md		54, 50, 11	8.4				
98	Timber Mill	N West	×	91—30, 40				35	
99	Process	NJ		92—30	12–15			35	45
100	Manufacturing	Ill		95	15 + B			37	42
101	Air Force	Ala		13	5.4		2		
102	Diversified Mfg.	NY		92—Mfg.	20–35				
103	Durable Goods	NY		11, 13, 21, 42	5.2–6.0				
104	Rug Mill	Pa		11, 13, 21, 42	6.0–7.0				
105	Electrical	Mass		92 or 37 or 11	6.5–11.0				
106	Sugar	ND, La, SC, Conn		13, 43			0		
107	Aircraft	Wash		13, 30					

INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel*	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
108	Mgmt. Consult	Overseas	×	10, 20, 60				35	40
109	Paper	NH			6.0–6.5				
110	Aircraft	Tex		11, 13, 19, 70	5.4–6.6				
111	Chemical	Ala			7.5				
112	Aircraft	Tex		11, 40, 70					
113	Chemicals	NJ		52					
114	Paper	Mo		11					
115	Foundry, Educ.	Pa							
116	Instruments	NY		71	–8.0				
117	Electrical	Mass		50					
118	Mfg.	Pa		11, or 16 or 37			4–8		
119	Paper	Ga		10, 20, 30, 42					
120	Air Force	Ga		I.E.	7.0				
121	Navy	Cal		11, 13, 42, 43, 53	6.1–7.6		2–6		
122	Navy	Va		I.E.					
123	Printing	NY		49, 53			2–4		
124	Mineral Prod.	NJ		11, 53			0–3		
125	Chemical	Mich		13, 21, 43, 33			1–5		
126	Boilers-Fdry.	O		10, 20, 30, 42, 43, 44	7.2			25	35
127	Theatrical	NY		42, 43, 45, 49	10–12		5–		
128	Cartons	Conn			4.8–5.9		0–3		35
129	Education	ND		Asst. Prof. I.E.					
130	Heat Exchangers	NY		92—37	8.0–10.0				
131	Radiators	Md		44, 48	6.5–7.6				
132	Oil Seals	O		10, 20, 42, 45, 53	6.0		2–	25	30
133	Flour Mills	Minn	×	11, 13, 42, 43, 94	7.2–8.4				40
134	Education*	W Va		52, 53					
135	Electrochemical	Midwest		92—80	15–20				40
136	Hospital	Pa		11	6.0–8.0		2–		
137	Copper†	Chile, S A	×	31, 39, 43, 64	9.0				
138	Wax	Wisc		11, 19, 42, 47, 81	5.9–6.9		2–4		

* Begins Sept.
† 3 yr contract.

AIIE OPPORTUNITIES SERVICE

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement
12	Suggestion Systems
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds.
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

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Industrial Engineering is concerned with the design, improvement,

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drawing upon specialized knowledge and skill in the mathematical,

physical and social sciences together with the principles and methods

of engineering analysis and design, to specify, predict,

and the